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THE UNIVERSITY OF ALBERTA

A COMPARATIVE STUDY OF CERTAIN PHYSICAL
AND MINERALOGICAL FEATURES OF
GREY WOODED SOILS

A DISSERTATION
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ABSTRACT

Certain physical and mineralogical characteristics of the Cooking Lake and Breton grey wooded soils were investigated. Physical analyses revealed little difference between the textures and porosity of these soils. Petrographic examination of the coarse and fine sand fractions of these soils showed no differences worthy of note. X-ray analyses of the clay fraction showed that the dominant clay minerals in these soils are montmorillonite and illite. The investigation suggests that the separation of these soils into different series is not justified.

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INTRODUCTION

The classification of soils into different series is a problem which often confronts the soil surveyor. Under field conditions a situation may arise where such differentiation is extremely difficult due to dominantly similar characteristics in two soils

In Alberta, the grey wooded soils cover a large portion of our surveyed areas. In the Peace Hills sheet located in central Alberta, Bowser et al. (8) mapped grey wooded soils and separated them tentatively into different series. These are termed the Cooking Lake and Breton series. The separation was made because these soils were thought to have developed over different parent materials. Slight differences were noted in the B horizon structure and laboratory analyses revealed the Cooking Lake had a higher magnesium content than the Breton soil.

Although the problem has not yet presented itself, it is realized that it would be virtually impossible to separate these two series in an area where they were interspersed. The U.S.D.A. Soil Survey Manual (61) defines a soil series as having soil horizons similar in differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil, and developed from a

particular type of parent material.

This report is the result of a preliminary study carried out to determine whether or not the separation of these soils into different series is justified. Any physical differences which exist between these two soils should be reflected in the morphological characteristics of the soils. Therefore certain physical analyses are to be carried out to ascertain whether such differences exist. It was hoped in this investigation to find an index mineral which would characterize the parent material of its origin. The recognition of such a mineral would assist in classifying not only these grey wooded soils, but also soils in the black soil zone which have developed over the same parent materials as those being investigated.

Review of Literature

Origin of the Term "Grey Wooded Soils"

At the first International Congress of Soil Science, Wyatt and Newton (65) in discussing Alberta soil profiles described "wooded soils" as being "podzol like." The soils are acidic down to the upper B horizon and the B horizons of these soils have a higher nitrogen content than the A₂ horizon. Joel (31) described similar soils in Saskatchewan as being "grey bush" soils. He found a similarity between these soils and the podzols described by Glinka. He noted that they differed in that the grey bush soils had a definite zone of calcium and magnesium carbonate accumulation. Wyatt and Doughty (64) refer to a soil profile as being "Grey (wooded) soil". Wyatt et al. (63) in describing wooded soils in the St. Ann sheet of central Alberta, stated that the loam soils, whether burned over recently or not, show on ploughing a greyish white appearance characteristic of the A₂ horizon of the wooded soil. It is undoubtedly due to this appearance that the name "Grey wooded" soils evolved.

Moss (45) in discussing the morphology and composition of Saskatchewan wooded soils, states that they do not fit into any of the great soil groups as defined but may be regarded as a branch of the Podzol family. Williams and Bowser (62) describe these soils as having developed in calcareous drift in a sub humid climate belt under a mixed conifer and hardwood forest.

Distribution of Grey Wooded Soils in Alberta.

Newton et al. (48) estimate that the grey wooded soil zone covers about two-thirds of the province of Alberta. In the explored region of this zone, the authors estimate there are fourteen million arable acres.

Climate under which development of grey wooded soils takes place:

Bowser and Erdman (8) and later Bowser and Peters (9) report that these soils are formed under sub humid conditions, that is, moderate rainfall and a low rate of evaporation. They report that the average annual precipitation over most of the Grey Wooded Zone is about nineteen inches, while the average annual temperature is about 35°F. Odynsky and Newton (49) mapped these soils in an area where the precipitation varied from 14.01 inches to 22.16 inches and they report that 34.3°F. is a fairly representative annual mean temperature for the area.

Williams and Bowser (62) note that grey wooded soils developed in Alberta and in the state of Montana, did so under sub humid climatic conditions.

Newton et al. (48) have reported that soils belonging to the wooded group have been produced at Fort Vermillion in Northern Alberta, where the mean annual precipitation is less than 11 inches. They submit that the development of such soils is due to the cooler climate and lower evaporation rates.

Ellis (17) states that these soils developed in

Manitoba under the influence of more moist conditions in the surface two feet of the soil than in the black earth and northern black earth regions. Williams and Bowser (62) note that Columbia Falls, Montana where the mean annual precipitation is about 20 inches and the mean annual temperature 44°F. is within the grey wooded soils belt.

Vegetation

Bowser et al. (8) state that under heavy woods in the Peace Hills sheet area, a grey soil develops. They list the dominant vegetation in the grey wooded soil zone as follows:

Trees and Shrubs

<u>Common name</u>	<u>Scientific name</u>
Aspen poplar	Populus tremuloides
Balsam poplar	Populus balsamifera
White Spruce	Picea glanca
Dogwood	Cornus stolonifera
Willow	Salix spp.
Currant	Ribes spp.
Honeysuckle	Lonicera involucrata
Rose	Rosa spp.
Cranberry	Viburnum pausi florum
Raspberry	Ribus strigosus

Native Grasses

<u>Common name</u>	<u>Scientific name</u>
Slender wheatgrass	<i>Agropyron pauciflorum</i>
Bearded wheatgrass	<i>Agropyron subsecundum</i>
Thickspike wheatgrass	<i>Agropyron dasystachyum</i>
Redtop	<i>Agrostis alba</i>
Bluejoint	<i>Calamagrostis canadensis</i>

Odynsky and Newton (49) discussing grey wooded soils state that the native cover consists of aspen poplar in which there are variable proportions of black poplar, spruce, willow, alder, birch and various shrubs. Leahey (39) states that there is evidence to verify the suggestion that spruce is the climax type of vegetation where grey wooded soils have developed.

Moss (45) states that while wooded soils studied in Saskatchewan are found under a mixed forest cover, the dominant vegetation is *P. tremeloides* and *P. balsamifera*. Further to this he notes that where spruce trees predominate, the soil is peaty in nature and of the poorly drained podzolic type.

Glassey (20) in discussing soils and vegetation in southwestern Wyoming, differentiates between podzol soils covered with a mixed growth of conifers and aspen trees and podzols developed at lower altitudes in small areas of aspen groves. He attributes the formation of the latter to extra water where snow drifts have accumulated

on these slopes.

Ellis (17) is of the opinion that the original vegetation under which grey wooded soils developed in Manitoba was spruce and allied boreal forests. However, due to forest fires, etc., the present vegetation is dominantly broad leaf trees which have become well established.

Williams and Bowser (62) state that grey wooded soils have developed under moderate to heavy stands of mixed conifer and deciduous forest, including poplar, spruce, fir, larch and ponderosa pine. Associated with the above is an undergrowth of shrubs and woody plants and a ground cover of creeping vine-like plants.

Dr. Kellog, who in 1951 visited the grey wooded soil areas in Alberta, reveals in a recent communique that he is of the opinion that aspen poplar is the climax vegetation of some of these soils.

Soil parent materials

Bowser et al. (8) state that Breton grey wooded soils are developed on parent material of Paskapoo formation origin. According to the above authors, the glacial till formed from the Paskapoo formation is brown in color, gritty and has a medium to medium high lime content. Allan (2) describes the Paskapoo formation as being lower Tertiary in age, a fresh water deposit, composed chiefly

of soft, grey, clayey and calcareous sandstones of soft shales and clays.

Bowser et al. (8) differentiated between the Breton and Cooking Lake grey wooded soils on the basis of structure [in the B horizon and the different origin of their parent materials. The Cooking Lake grey wooded is of the Edmonton formation origin. Allan (2) states that the Edmonton formation consists largely of sediments deposited under fresh and brackish water conditions. The formation is composed of fine grained sandstones, highly calcarious sandstones, sandy shale, bentonitic sandstones and shales, bentonite, ironstone bands, carbonaceous shales and coals. Bentonite prevails through the whole series of beds, which vary greatly both laterally and vertically.

Since this work deals specifically with the Cooking Lake and Breton grey wooded soils, it is felt that the above sufficiently describes the parent materials and the parent rock of these soils. However, it should be noted that grey wooded soils have developed on material other than till, for example on outwash and lacustrine deposits and on other parent rocks as described by Odynsky and Newton (49). According to Williams and Bowser (62) all of the drift area in Montana and Alberta where these soils have developed is of the Wisconsin age.

Morphology of Breton and Cooking Lake grey wooded soils

Bowser and Erdman (op cit.) describe the Breton profile as follows:

- | | | |
|--------------|----------------|------------------------------------------------------------------------------------------------------------|
| 1 - 3 inches | A ₀ | Leaf mat |
| 1 - 2 | " | A ₁ Dark brown loam |
| 4 - 7 | " | A ₂ Light grey brown, platy loam to sandy loam, easily crushing into small irregular fragments. |
| 1 - 2 | " | A ₃ Brown, porous, firm, breaks into nuciform fragments. |
| 10-20 | " | B ₂ Brown to dark brown clay loam to clay, medium nuciform to blocky. |
| 10-20 | " | B ₃ Brown medium nuciform but less well defined than B ₂ . |
| | Ca | At average of 48 inches from the surface, often spotted with lime. |
| | C | Fairly uniform brown sandy clay loam to clay till. Highly siliceous. |

The above authors also describe the Cooking Lake solum characteristics as being very similar to the Breton grey wooded solum, the main differences being that the B horizon is more strongly stained and more blocky than in the Breton profile. Also, as has been previously mentioned, these soils are developed on different parent materials. Williams and Bowser (62) give the chief characteristics by which these soils may be recognized: a platy A₂, grey in color; a nuciform or blocky B₂ which is well developed structurally, having its aggregates stained or glazed with

brown or dark brown colloidal organic matter; a solum seldom over four feet thick, having a horizon of lime carbonate accumulation and developed over calcareous material.

Porosity on pF measurements

Nelson and Baver (47) in a series of experiments using a number of different size grades of sand, were able to show that drainage of such a porous system was determined by the size of the neck between the individual grains of sand. Curves relating pF to moisture content were plotted for the various grades of sand and compared with sized aggregates of different soils in an attempt to determine the size of the non capillary pores. Leamer and Shaw (40) studied large numbers of soil samples, measuring the capillary porosity using a blotter apparatus to determine the pF values. Smith, Browning and Pohlman (58) studied the percolation through undisturbed soil cores. The cores were saturated and then subjected to a desired tension. The volume of water removed was used to determine the pore size distribution of the soils.

Petrographic Methods As Applied To
Soil Mineral Analyses

Soils are basically composed of the disintegration and decomposition products of rock, plus organic matter. If the organic matter is removed from the soil, the residue may be expected to be composed of common rock forming minerals and their decomposition products.

Fry (18) outlines the use of petrographic methods as they may be applied to soils minerals. Quantitative methods are applied to the mineral determinations of sized soil separates.

Hart (22) carried out a detailed study of soil minerals over a region of diverse rock and found that a similarity could be established between the parent rock and the drift over-lying the rock; only rarer minerals were derived from external sources. The varied nature of the parent material evidently gave rise to varied textures in soils. Hart, discusses in some detail, the work of Hall and Russel, who in a survey of the soils of Kent, Surrey and Sussex, found that their soil type boundary coincided with the boundaries of the geological formations. However, texture is the main point considered as they state, "All of our experience in the field goes to show that each geological formation in the area under

consideration gives rise to a distinct soil type characterized by its mechanical analysis".

Hart (22) found that soils could be related to underlying rock through the drift, except in cases where outcrops at right angles to the direction of ice movement are narrow and the drift is thick. He suggests that a determination of the mineralogy of the matrix of the drift is useful in determining the distribution of the drift and in forming a basis for the grouping of soils.

Hendrich and Newlands (25) compared soil samples from certain localities in England with samples from N.E. Scotland. Using heavy liquids and an electro magnet, the soil minerals were divided into three groups: 1. orthoclase, 2. quartz and 3. ferro silicates. The soils examined were of glacial origin and differed in mineral content according to the nature of the parent rock from which the drift was taken. Soils from sediments were almost entirely quartz, while soils of parent rock which were of basic igneous origin were very low in quartz and high in ferro silicates.

Carroll (14) carried out a study on the mineralogy of west Australian soils and concluded that the character of the heavy residue of the soil often gives a clear indication of the nature of the parent

rock. Secondly, that the diagnostic value is enhanced by the amount of heavy minerals, by distinctive features of a mineral species and by the amount of magnetic material present. The soils studied were formed in situ by weathering of underlying rock.

Kruger (35) is of the opinion that few mineral species are diagnostic of any one drift sheet. He states that the drift sheets of Minnesota have been re-worked and therefore their mineralogy has been complicated. The distribution of heavy minerals in all the drifts is similar to their distribution in freshly crushed granite. This fact suggests leaching and weathering are slight; the only suggestion of weathering was an abundance of hydrated oxides of iron and few varieties of some mineral species.

Goldthwaite and Kruger (19) examined the heavy mineral distribution of fresh and rotted parent rock, the till and the sola developed over the till. They found that the till is uniform in fresh abraided rock. The clean appearance of some of the minerals suggested that they were derived from fresh rock rather than weathered rock. The authors suggest that interglacial weathering took place to a greater extent than during the post glacial period.

Buckhannan and Ham (11) carried out mineralogical

studies of soils and their parent materials in Central Oklahoma. They found the presence or absence of certain heavy minerals valuable in identifying parent materials, where terraces have been obscured and origin cannot be determined by texture or consistency. These differences had been noted in the heavy mineral suite of sediments which were possible parent materials.

Allen (3) made thin sections of desired horizons of a soil sampled in a columnar unit. The soil was impregnated with kolloid and then ground to the desired thickness. The study of these thin sections revealed a definite weathering of feldspar, hornblende and epidote to produce beidellite. It was indicated that under good drainage conditions, the clay produced from weathering in the upper horizons is translocated and deposited in lower horizons.

Jeffries and White (28) carried out a mineralogical analysis of the very fine sand separates on four podzolic soils developed on different parent materials. The very fine sand was separated into three groups by the use of heavy liquids. The heavy group including minerals heavier than specific gravity 2.70, the quartz group with a specific gravity less than 2.65 but greater than 2.55 and the feldspar group with a specific gravity less than 2.55. The heavy and feldspar groups were

studied microscopically to determine and compare minerals in the different soil profiles. The above authors found that quantities and kinds of minerals were typical of a profile. Each profile had some outstanding mineral characteristics which distinguished it from the others. They suggest that these differences were due to differences in parent materials and as such should prove useful for correlation purposes and soil classification.

Jeffries (27) has outlined a procedure for the study of the mineralogy of the fine sand separates of some Pennsylvannia soils. The fine sand was separated into three mineral groups by the use of heavy liquids and a specially designed separatory funnel. These were heavy mineral, quartz and feldspar groups. He concluded that the mineralogical composition of the very fine sand separates varied considerably in amounts, but little in variety of mineral species. Outstanding minerals of general occurrence in the soils are useful for purposes of correlation, comparison and as an aid in soil classification. The mineral contents of the parent rock and soil developed on carbonate rocks from four locations were studied by Jeffries and White (29). They studied the very fine sands of a hydrochloric acid insoluble residue of the parent rock and horizons of the different soils. In addition, thin sections were made of the parent rock. The sands were separated into three fractions

by methods previously outlined by other authors. Three different types of parent rock were determined: limestone, chemical dolomite and clastic dolomite. In general it was found that minerals present in the very fine sand separate of the parent rock were reflected in the soil developed over them. However, in the case of the soil developed over a clastic dolomite, minerals were present in the soil which could not be accounted for in the parent rock. The authors suggest that this may be due to the manner of formation of the clastic dolomite. Using the variations in proportions of weathered and fresh feldspar, a zone of intense weathering was indicated which is adjacent to the parent rock. Although the type of feldspar gave different relationships, the same trend was apparent.

Cady (13) carried out investigation on two soils in the Central Adirondack section of New York.

These soils were: (a) A podsol soil developed under a spruce hardwood cover.

(b) A brown podzolic soil developed under a hardwood cover.

The two were interspersed on the same (glacial till) parent material under identical climatic conditions. Eight profiles were selected and samples of the sand fraction size 0.044 to 0.015 mm. were examined petro-

graphically. All of the grains in the C horizons were clear, sharp and unaltered. Quartz was the most abundant, followed by feldspars. Of the heavy minerals, the most abundant was hornblende, followed by magnetite, garnet, hypersthene and augite. In the A horizon of the podzol soil, there was a marked decrease in the hornblendes and other easily weathered species. In the brown podzolic A horizon minerals were found in similar amounts and proportions to the C horizon. Although some etching was noted in the hornblendes and feldspars, Cady noted that green hornblende was an excellent indicator of the intensity of podzol weathering. The heavy fraction containing a large proportion of ferro magnesian minerals, increased under brown podzolic weathering. Cady concluded by suggesting that on the basis of his work, the establishment of a new great soil group, the brown podzolic was justified.

Richard and Chandler (53) studied three profiles located in Eastern Quebec. These profiles were mature podzols developed on till of schist and sandstone parent rock. The fine sand fraction was used for mineral analyses and two separations were made, quartz and feldspars and heavy minerals. There was a definite and intense weathering of the schist fragments in the A₂ horizon which decreased with depth. Of the heavy minerals,

hornblende and hypersthene weathered rapidly in the A₂ horizon as compared to slight weathering in the parent material. The relative amounts of garnet and zircon increase in the A₂ horizon since other minerals have decreased, actually the garnet-zircon ratio is approximately the same in the A and C horizons. Both minerals are highly resistant to weathering.

Matelski and Turk (44) divided two podzol soils in Michigan into two groups. One group supported a hardwood forest and the second a pine forest cover. They corroborated the fact that hornblende (dark green variety) was the easiest-weathered mineral, followed by opaque minerals and garnets. Relative resistance to weathering varied within the profile; generally greater mineral decomposition was noted in the B horizon than in the A and C horizons. The intense brown color in the B of soils supporting a hardwood cover is thought to be due to inorganic colloids. The authors suggest that this may be explained by the greater original content of opaque and ferro magnesian minerals and subsequently more intense decomposition. The soils supporting a hardwood cover contain a greater quantity of calcium carbonate and heavy minerals in all horizons than do soils supporting a pine cover.

Haseman and Marshall (24) outline a semi-

quantitative method for using presence of heavy minerals to identify parent materials. They conclude that the origin of soil is reflected in the kinds and amounts of heavy minerals present. They suggest that a qualitative determination of the heavy minerals is sufficient to indicate the origin after the kind and abundance of these minerals have been determined in possible parent materials. It is of considerable importance that, in making heavy mineral comparisons between soils and parent materials, the same size fractions be used. The authors found that differences in the origin of parent materials at different depths are readily shown by heavy mineral analyses. Again hornblende, because of its wide distribution and moderate resistance to weathering processes, is a good comparative mineral in estimating the weathering in different horizons of the soil.

Marshall and Jeffries (43) explain in detail mineralogical methods for correlating soil types and parent materials. In the method outlined the authors use the very fine sand and silt soil separates. Using tetrabromethane and nitrobenze for making liquids of varying densities, the separates are divided into three groups. These are:

Heavy mineral group	S.G. 2.95
Mica group	S.G. 2.95 - 2.70
Felspar and quartz group	S.G. 2.70

A number of special centrifuge tubes designed for this work are illustrated by the authors. The minerals are mounted on a gelatin slide and determined using standard petrographic methods. In concluding, the above authors suggest that three size fractions should be examined separately and together due to the eventuality that a mineral may weather out of a finer before disappearing from a coarser fraction.

Rice and Atkinson (5) analyzed three Canadian soils for mineral content: Regina clay, Rideau clay and North Gower clay. The authors explain that this work was exploratory. However, in their findings orthoclase was found to be much more prevalent in the Regina clays. It was felt that this factor may be associated with the greater proportion of clay in the Regina clays. The above authors carried out a detailed study of eight horizons of a brown podzolic soil from Quebec. Approximately sixty-eight minerals were identified in the heavy fraction. Hornblende, zircon and garnet had accumulated in the A_1 horizon due to the disappearance of less resistant minerals. The A_2 horizon had an accumulation of ferro magnesian materials due to the weathering of brown hornblende. In the B and C horizons the authors suggest that the accumulation of less resistant materials was due to less weathering or

their translocation from upper horizons.

In that fraction of specific gravity 2.95 - 2.66 plagioclase accounted for 50 percent of the total and considerable muscovite was present. The fraction with specific gravity less than 2.65 was very small, with a small mineral suite.

Clay Minerals and Their Occurrence in Soils

The clay fraction of soil differs from silt mineralogically, in that it consists of the secondary products of weathering which are not found in unweathered rock. According to Russell (55) these secondary clay minerals rarely occur in particles larger than two microns and are much more resistant to weathering in the soil than are rock minerals ground to a comparable size. Grim (21) states that in defining the term clay, three implications must be considered. These are:

- (1) A natural material with plastic properties.
- (2) A material having very fine size grades.
- (3) A material composed of crystalline fragments of minerals that are mainly hydrous aluminum silicates and occasionally hydrous magnesium silicates.

Grim reports that kaolinite, illite, montmorillonite

and sometimes halloysite, have been found in soils.

These clay minerals are all similar in crystal structure, being composed of layers or sheets of oxygen, silicon and aluminum atoms. Two types of layer lattices have been recognized, that type which is associated with kaolinite and the type common to montmorillonite. Montmorillonite may be described as having a 2:1 lattice crystal structure, that is, 2 silica sheets to 1 alumina sheet. It has an expanding lattice and is thought to be mono clinic with a probable composition of $(OH)_4 Al_4 Si_8 O_{20} \cdot xH_2O$. Kaolinite has a 1:1 lattice, that is one alumina sheet to one silica sheet. It has a non expanding lattice. Kaolinite is thought to be mono clinic with a composition of $(OH)_8 Al_4 Si_4 O_{10}$. Illite has a structure similar to montmorillonite, a 2:1 lattice. However, about 15 per cent of the silicon atoms are replaced by aluminum atoms. The excess charges are satisfied by potassium ions which, it is considered, act as a bridge between the layers and prevent expansion of the lattice. Illite is thought to ^{be} mono clinic and has a general formula of $(OH)_4 Ky (Al_4 Fe_4 Mg_4 Mg_6) Si_{8-y} Al_y O_{20}$. Halloysite is very similar to kaolinite in crystal structure, composition and properties. Kaolin is white in color, while illite and montmorillonite may be white, yellow,

green, or pink. These are the common clay minerals found in soils, they are all thought to be monoclinic and exhibit good basal cleavage. Montmorillonite and kaolinite are commonly formed by soil forming processes; illite is seldom formed in this way. Montmorillonitic and kaolinitic soils may be formed from illitic material and kaolinitic soils from montmorillonitic parent material. The author states that there is no unquestioned example of a montmorillonitic soil that has developed from kaolinitic parent material.

Nagelschmidt (46) studied the mineral constituents of the colloidal fraction of red and black earths developed on the same parent materials from Hyderabad, India. Both of these soils occurred in the same field and were derived from the same parent rock materials, a coarsely crystalline granite or gneiss. The clay fraction was divided into three fractions, these were:

Coarse clay	1.4 - 0.1u	diameter
Fine clay	0.1 - 0.06u	"
Super fine clay	under 0.06u	"

The author found that the red clay contains predominantly kaolinite or halloysite. He suggests that these minerals were formed under acidic or neutral conditions.

Beidellite, a member of the montmorillonite group, was dominant in the black clay and according to the author,

forms under alkaline conditions. Nagelschmidt is of the opinion that topography is the main factor associated with the difference in minerals in these soils.

Kelley et al. carried out extensive studies of the colloidal constituents of California soils. These were formed on two different parent materials, alluvium, developed from sedimentary and igneous rock and a residual material, developed on igneous and sedimentary parent rock. The author states that every colloid studied is definitely crystalline and composed chiefly of clay minerals of definite types. It was possible to determine the clay minerals present in the soil colloids by comparing the x-ray diffraction patterns with those of known minerals. Such determinations are facilitated by x-raying the samples at widely varying moisture contents. Kelley was able to show that certain of these soils were predominantly high in one of three clay minerals: montmorillonite, kaolinite and a mineral he called x clay mineral, thought to be illite. In addition to the clay minerals, quartz, rutile and zircon were also present. The profiles of several American alkali soils drawn from different localities in Western United States were studied by Kelley et al. (33). X-ray investigation revealed that the white-alkali soils

contained a mixture of montmorillonitic, kaolinitic and mica-like clays. The mica-like clays predominated in the black alkali soils. The soils showing solonetz structure had clay minerals which were predominately mica-like. The authors state that considerable variation seems to be characteristic of the mica-like clays and suggest that such may be due to variations in the type of mica in the parent rocks of the soil materials. Kelley is of the opinion that clay minerals found in alluvial alkali soils have been inherited as constituents of the alluvium and are not necessarily pedogenic in origin. Coleman and Jackson (15) studied the mineral composition of twelve representative soils of the Coastal Plain and adjacent soil regions of south eastern United States. X-ray diffraction patterns were obtained of the coarse clay (0.2u to 2.0u) and the fine clay (less than 0.2u). Montmorillonite was found to be abundant in the majority of the fine clay fractions and was present in the coarse clay fraction. The only exceptions to this were two highly weathered soils in which kaolinite was dominant in both the coarse and fine clay fractions. Illite was present in the coarse and fine fraction of most soils. Quartz constituted

approximately fifty percent of the coarse clay except in the highly weathered profiles, where it did not exceed ten percent. Quartz constituted less than five percent of the fine clay in these soils. The authors concluded that the clay fractions of these soils are usually mixtures of three or four mineral components with montmorillonite considerably more prevalent than was previously thought to be the case. Kaolinite, while predominant in the highly weathered soils, is present in lesser amounts than had been expected in soils of rather wide occurrence in this region.

A solodic soil profile from Wilkin County in the Red River Valley, Minnesota, was investigated by Brown and Caldwell (10). This soil was developed on a lacustrine deposit under arid and semi-arid climatic conditions. The authors found that montmorillonite was the dominant clay mineral in this soil. Illite was noted in the A horizon and possibly kaolinite in the parent material. Quartz was present in all horizons. They suggest that the dominance of montmorillonite in this profile indicates that it has developed under arid and semi-arid conditions. The characteristics of the clay fractions of planosol and chestnut soils taken from eastern Nebraska, were studied by Larson et al. (36). These soils were developed in sub-humid and semi-humid

areas where the processes of weathering and soil development were less intense than in humid areas. The authors found that the clay fractions from all horizons where weathering would be expected to be more intense are similar to clay fractions from deeper and presumably less weathered horizons. This indicated that the clay forming processes have been similar throughout the entire development of these soils. An increase in the clay content is not accompanied by a notable change in clay mineral content. Since kaolin was not identified as being present in these soils, apparently it is not produced by weathering of loess or the calcareous till under conditions in eastern Nebraska. The authors found the iron rich member of the montmorillonitic group of clay minerals to be dominant among materials containing basic constituents. There appeared to be an indication of weathering of coarse clay in the surface horizon with a subsequent increase in quartz content.

Alexander et al. (1) studied mineral constituents of soil colloids from a group of United States soils including red podzolic, grey brown podzolic, prairie chernozem and desert. In general the colloid studied was from the B₂ horizon of these soils. Montmorillonite was identified only in the chernozem and prairie soils. These soils are developed on till. The authors state

that the results obtained indicate prominent differences between colloids from B horizons of different soil groups. The data obtained revealed that the red podzolic soils contain kaolinite as the dominant component accompanied by large amounts of hydrous oxides and free oxides of iron. The grey brown podzolic has both kaolinite and hydrous mica as prominent components, accompanied by an appreciable amount of free oxides and hydrous oxides of iron.

Peterson (52) studied the relation of parent materials and environment to the clay minerals in a group of soils along the lower Des Moines river in Iowa. The author found that Iowa soils with parent material of pleistocene origin are characteristically high in montmorillonite. However, the proportion of montmorillonite to kaolinite varied according to climate, vegetation and source and age of parent materials. Generally in soils on older pleistocene materials, this proportion is lower in both A and B horizons. This shift is greater in podzolic soils than in prairie soils. There is evidence that there is an increase in the amount of montmorillonite in clay in the B horizon in areas of greater rainfall. Soils developed from glacial till, residual material, terrace and bottom land in Union County, Pennsylvania, were investigated by Jeffries and Yearick (30). The clay

minerals were found to be essentially chlorite and hydrous mica with a trace of quartz. The authors concluded that the differences in these soils in the distribution of these minerals were due to depositional processes and material of preglacial origin. This was concluded from the sharp differentiation between the clay mineral patterns of the A and B horizons in some soil profiles and the absence of such differentiation in others. Two processes of deposition were traced to account for such differences.

Pearson and Ensminger (50) reported on twelve Alabama soils which represented the following physiographic regions: the Coastal Plains, Piedmont, Black Belt, Limestone Valley and Appalachian Mountain area. The soils could be divided into two groups: those containing no detectable amounts of montmorillonite and those in which montmorillonite was dominant. The authors found that the concentration of montmorillonite has no apparent relationship to the soil pH. The kaolinitic soils contained relatively large amounts of iron oxide, and quartz and kaolinite increased in concentration from the surface to the weathered parent material in every case. Quartz occurred in greatest percentage at the surface and decreased sharply with depth. Very little mineralogical variation was noted

in the montmorillonitic soils with depth.

Buehrer et al. (12) studied the principal soils under cultivation in Arizona. The dominant clay minerals were montmorillonite, illite and kaolinite. In these profiles montmorillonite tended to increase with depth. The authors noted that poor structural characteristics were associated with soils high in montmorillonite.

Peterson (51) has shown in laboratory experiments with synthetically produced soil aggregates that kaolinite is associated with platy structure in soils. Using mixtures of commercial montmorillonite, kaolinite and sand, Peterson duplicated the platy soil structure that is often apparent in podzolized soils. Studies of the clay minerals of field soils substantiated his findings. Peterson states that "from the data obtained it may be surmised that platy structure in soils can be expected to develop within comparatively shallow depths of the profile in layers containing kaolinite without abundance of montmorillonite, in the absence of appreciable amounts of humus, calcium and iron oxides and in a zone free of extensive root activity such as would be found under a native prairie sod". The author noted that in general podsol soils showed a higher proportion of kaolinite in the A horizon and a higher proportion of montmorillonite in the B. The oldest soils studied, that is soils developed on Kansan or Nebraskan tills, show a much higher proportion of kaolinite than do other Iowa soils. The platy A horizons show a marked

increase in kaolinite. Peterson states that it is quite possible that the high amount of kaolinite in these soils of earlier glacial periods may be characteristic of the parent material rather than of pedogenic processes. If the shift in favor of kaolinite has occurred since the deposition of the original material it may indicate either the formation of kaolinite as a weathered product or the loss of montmorillonite through decomposition or eluviation.

Bidwell and Page (7) studied the dominant soil catena of the west central Ohio, late Wisconsin, glacial till plains. These soils, derived from similar parent material, a high lime glacial till, differ largely because of drainage as influenced by topography. The soils were formed under forest vegetation. The illitic type of clay mineral was dominant in every profile investigated. The presence of this mineral in the parent materials of each of the profiles studied, indicates that a large part of this type of mineral occurring in the solum, may have been inherited from the parent material and is not of pedogenic origin. In the less well drained members of the catena, there was evidence of montmorillonite in the B horizons which seems to indicate that soil formation processes have caused production of this mineral since deposition of the till. There was little evidence, however, to show that the different internal drainage conditions under which these

soils are found have produced any appreciable amounts of different types of clay minerals in the different profiles.

Rice and Atkinson (5) have carried out some preliminary studies of Canadian soils. Three clay soils used were: Regina clay from Saskatchewan, Rideau clay from Ontario, and North Gower clay from Ontario. Also investigated was a brown podzolic soil from Quebec. The results obtained suggest that Regina clay is high in montmorillonite. The North Gower clays and Rideau clays show the presence of illite, with some indication of montmorillonite; kaolinite was also suggested as being present in the Rideau clay. In the brown podzolic profile, four horizons were studied. Montmorillonite and illite were shown to be the predominant clay minerals. The authors suggest that illite in the profile may be derived from the micas in the parent material, or as a result of soil development processes.

OUTLINE OF INVESTIGATION

This work involves a comparative study of two grey wooded profiles: the Cooking Lake grey wooded, which is developed on material of Edmonton formation and the Breton grey wooded, developed on material of Paskapoo formation. It is also thought that Bearpaw shale may be mixed with the parent till of the Cooking Lake grey wooded soil.

Information at the present time suggests that these two soils should be differentiated on the basis of their parent materials, plus slight differences in profile

characteristics. While this work involves only the grey wooded soils, these parent materials occur in the black soil zone and therefore the same problem arises there regarding series separation.

In this investigation it is hoped, if possible, to determine whether there are sufficient differences in the parent materials to justify placing these soils in separate series.

Description of the sample areas

The sample area for the Cooking Lake grey wooded soil lies approximately twenty miles east and southeast of Edmonton in the Beaverhills moraine. The sample area for the Breton grey wooded lies approximately forty-five miles south west of Edmonton, between Pigeon Lake and the town of Breton. This area may be considered a part of the Duffield moraine. The topography of the sample area is morainal, swell and swail. The vegetation and climate under which these grey wooded soils were developed has been previously discussed and applies to the sample areas.

Plan of investigation

The soils were sampled during the summer of 1950. Three locations in each area were sampled. They were then returned to the soils laboratory at the University of Alberta to be prepared for investigation. It was thought that physical and mineralogical analyses would indicate whether the parent

materials and soils developed over them were sufficiently dissimilar to warrant a series separation. The information obtained may also aid in interpreting certain physical and fertility aspects of these soils, which is of utmost importance to the soil surveyor.

MATERIALS AND METHODS

Sampling

As much as possible, all locations that were sampled, were identical with respect to topography, vegetation and climate. The samples were taken on a northern exposure, with a slope of approximately three percent. The sample locations were relatively the same position on the slope.

Six horizons in each profile were sampled: these being the A₂, AB, B₂, B₃, Bca and parent material (P.M.). The parent material samples were taken well below the horizon of lime accumulation, where it was thought the least amount of weathering had taken place. The specific locations of the samples are listed below.

Cooking Lake grey wooded

Location no. 1	N.W. 7 - 51 - 21 - 4
Location no. 2	S.W. 30- 52 - 23 - 4
Location no. 3	N.E. 22- 51 - 22 - 4

Breton grey wooded

Location no. 1	N.E. 10 - 47 - 2 - 5
Location no. 2	N.E. 33 - 46 - 3 - 5
Location no. 3	N.E. 23 - 47 - 4 - 5

The morphological characteristics of these soils have been discussed in detail previously in this work. The description may be applied to the profiles sampled above, so that it does not seem necessary to go into further detail regarding these samples.

Soil cores were taken of the parent materials of these soils at locations one and two. The cylinders were forced into the soil to a depth of 4 inches and then dug out. The excess material clinging to the cylinder was carefully removed. The core was then placed in an air tight container and returned to the laboratory and waxed to prevent drying out.

Preparation of samples

The samples were spread out and allowed to become air dry, at room temperature, in the laboratory. From each of the air dry parent materials samples, a number of clods were removed and set aside for volume weight determinations. The air dry samples were then passed through a screen with openings two millimeters in diameter. The material which passed through this seive was bottled and stored for future analysis.

Preparation of composite samples

It seemed likely that any physical and mineralogical differences in the two soils under consideration would be most likely shown in those horizons where the morphological characteristics were dominant. These horizons in both soils under consideration were A₂, B₂, Bca and the parent material. It was therefore decided to make composite samples for each of the above horizons from the Cooking Lake and the Breton soils.

One hundred grams of sieved soil were taken from each of the above horizons from the three locations in Cooking Lake and Breton sample areas. The three hundred grams of soil were then thoroughly mixed.

The resulting composite samples of the A₂, B₂, Bca and parent material for each of the two soils were bottled for future analyses.

Physical Analyses

Determination of apparent specific gravity

The apparent specific gravity was determined using the paraffin immersion method as outlined by Shaw (57), Lauritzen (38) and Lauritzen and Stewart (37). The workers listed above used clods under field conditions. In this work, structural units taken from the profile were oven dried first (110°C.), then the apparent specific gravity determined

by the method they outline. Nine determinations were made on the parent materials from each location. The average figure for these determinations was taken as a representative of the apparent specific gravity.

Determination of real specific gravity

The real specific gravity of the parent materials of these soils was determined by means of a pycnometer. The procedure followed is outlined by Lyon and Buckman (42). Three determinations were made on the parent material taken from each location. The average figure for these determinations was taken as representative of the real specific gravity.

Determination of percent pore space

Baver (6) gives the formula used in determining the percent pore space of these parent materials. The values for A.S.G. and R.S.G. used in this formula were obtained by the methods previously outlined.

Mechanical analyses

The mechanical analyses of these soils was determined by the pipette method. The procedure followed was in general the same as described by Kilmer and Alexander (34) differing in pre-treatment with HCl and removal of the dissolved mineral matter as follows:

(1) To the 10 gram sample of air dry soil sufficient H₂O was added to bring the sample into suspension by stirring. Sufficient 1N. HCl was added as was necessary to adjust the pH

of the suspension to 3.5 (spot plate test, bromphenol blue indicator). The organic matter was removed according to the procedure outlined by the above authors.

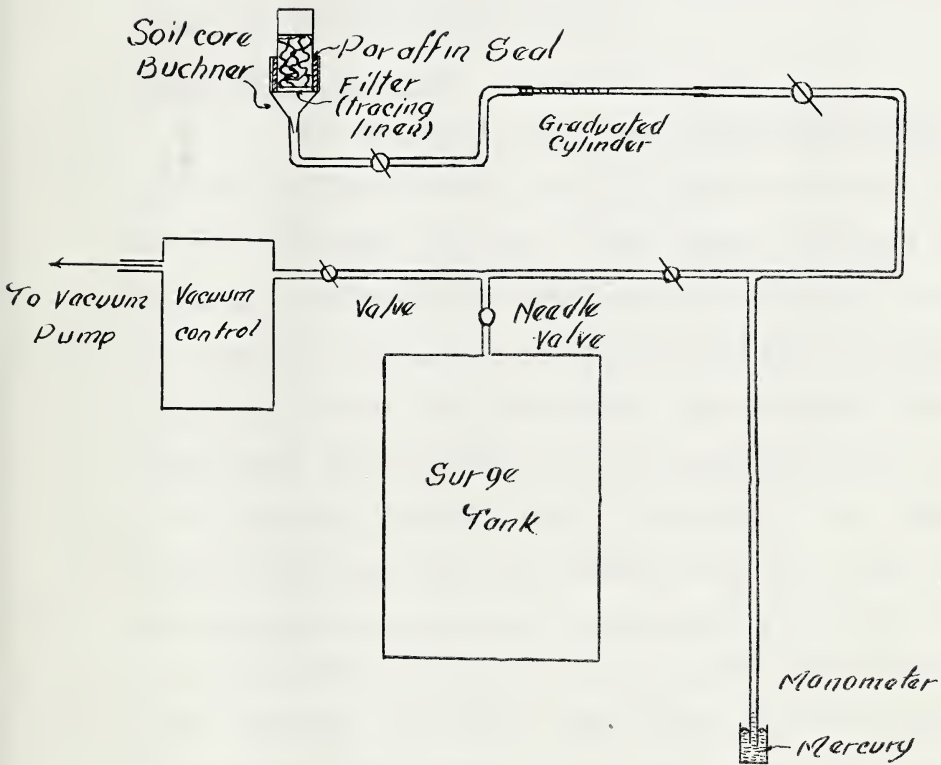
(2) Following the hydrogen peroxide treatment, the soil was removed from the beaker to a 100 ml. centrifuge tube using a rubber policeman and a strong jet. The suspension in the centrifuge tube was brought up to 90 ml. by adding distilled H_2O . The pH of the suspension was adjusted to 3.5. The tubes were then centrifuged until the supernatant liquid was clear. The supernatant liquid was removed using suction. The soil was washed in this manner six times. Following the last washing, the supernatant liquid was removed and the soil transferred to a 50 ml. beaker using a rubber policeman and a strong jet. The beaker was then dried on a steam bath and placed overnight in an oven at $110^{\circ}C.$, cooled in a dessicator and then weighed to the nearest milligram. The weight of the oven dry organic-free sample is used as a basic weight for calculating the percentages of the various fractions. The procedure from this point on followed that of Kilmer and Alexander.

Pipettings were made at 10 cm. depths for 20u, 5u and 2u particles. The settling times were determined from Stokes' law as shown by Bayer (op cit.).

In addition the clay fraction less than 0.2u was determined using the centrifuge method outlined by Steele and Bradfield (59).

Diagram I

Apparatus for determination of soil pF.



The mechanical analyses described above were carried out on each of the composite samples from the Cooking Lake and Breton soils. In addition, mechanical analyses were carried out on samples of the A₂, B₂, Bca and parent material horizons for each of the three locations in the two sample areas.

Determination of pF

The apparatus used for the determination of soil pF was similar to that used by Lutz and Leamer (41) and Nelson and Baver (op cit.) The vacuum pressure control apparatus built in the physics laboratory at the University of Alberta was similar to that described by Richards (54). Diagram 1. shows the apparatus. The vacuum control permits adjustment of the tension to any desired level. The surge tank prevents fluctuations in pressure. The amount of water withdrawn from the saturated core at each tension was measured by means of a graduated cylinder. From this is calculated the amount of pore space filled with water at each tension. The total pore space has been previously discussed. The volume of the soil core was determined and the percent water by volume was calculated from the volume of water removed from the core at each applied tension. The different tensions used were converted to pF values by taking the common logarithm of the manometer readings

(expressed in centimeters of water) and graphed as is shown in Fig. 6.

Mineralogical analyses of the soils

The A₂, B₂, Bca and P.M. composite samples of the Cooking Lake and Breton grey wooded soils were selected for mineralogical analyses.

The procedure followed in preparing these soils for mineral analyses is outlined by Jackson et al. (26). In order to ensure having a sufficient amount of clay, 60 grams of soil were used from each of the A₂ samples, while 40 grams were used from the B₂, Bca and P.M. samples.

The sands obtained from the parent materials of these soils were sieved. Of the sieved material, the coarse sand (1.0 - 0.5 mm.) and the fine sand (0.25 - 0.1 mm.) were used for mineralogical determinations. These sands were separated by using heavy liquids at a specific gravity of 2.95. A method for such separation is described in detail by Marshall and Jeffries (43). The separates were then analysed by standard petrographic methods. It was believed that any differences in the mineral content of these soils would most likely be indicated in the parent materials where the mineral fraction was least subject to weathering. Therefore it was not felt necessary to make a petrographic study of the mineral fraction of the other horizons. The clay present in the samples was divided into two fractions, coarse

clay (2.0u - 0.2u) and fine clay (0.2u and less). The separation of these two fractions was accomplished by using a centrifuge. The length of time required for centrifuging was determined from the formula given by Steele and Bradfield (op cit.). The two clay fractions were then removed from the centrifuge tubes. The clay suspension was condensed into a smaller volume, ready for x-ray analyses.

The petrographic and x-ray analyses of the sand and clay fractions of these soils was carried out under the direction of Dr. H.J. Atkinson, Head of the Soil Chemistry Unit, Science Service, at Ottawa. The following description of the method used was forwarded by Dr. Atkinson.

"A Philips 1950 x-ray spectrometer and large cameras were used with $\text{CuK}\alpha$ and $\text{FeK}\alpha$ radiation. Smears were made from the sample suspensions, using microscope slides. The smears were then x-rayed with $\text{CuK}\alpha$ radiation and Ni-filter at 40 KV, 20 MA and spectrometer rate meter settings of 4-1-8 and 8-1-8.

Ten-milliliter samples of the suspension were kept in reserve and the remainder taken to dryness at 80°C. The dry samples were analysed with $\text{CuK}\alpha$ radiation, Ni-filter and a spectrometer setting of 4-1-8 at 1°20 under the following conditions.

- (1) Dry sample - general run, CuK , Ni , 40 KV
20 MA.

- (2) Ignited to 350°C . for $\frac{1}{2}$ hour to check for sepiolite and treated as in (1).
- (3) Ignited to 600°C . for $\frac{1}{2}$ hour to check for the kaolinite group and treated as in (1).
- (4) Ignited to 700°C . for 4 hours to check for vermiculite and treated as in (1).

Dry samples were treated with ethylene glycol and x-rayed in large cameras with $\text{FeK}\alpha$ and Mn filter at 45 KV, 10 MA for 20 hours and used for the estimation of montmorillonoids."

RESULTS

Table I shows the apparent specific gravity of the parent materials of the soils under consideration. The average figures for the three locations of each soil series indicate that the Cooking Lake has a higher apparent specific gravity than has the Breton parent material.

Table II shows the real specific gravity of the Breton and Cooking Lake soil parent materials. The average figures for the three locations of each soil series indicates that there is little difference between the two parent materials.

Tables III and IV show the per cent pore space of the parent materials of these soils. The pore space is determined for each sample location in the two soil series. Cooking Lake parent material is shown to have a much lower per cent pore space than the Breton.

TABLE I

Apparent specific gravity of Cooking Lake and Breton grey wooded soil parent materials from three locations as determined by the paraffin immersion method.

Cooking Lake			
	<u>Site 1</u>	<u>Site 2</u>	<u>Site 3</u>
Depth	80"	60"	72"
	1.82	2.03	1.94
	1.93	2.21	1.95
	1.91	2.01	2.05
	2.01	2.09	2.13
	1.99	1.91	2.09
	2.01	2.09	2.13
	1.99	1.91	2.09
	2.01	1.95	2.07
	2.06	1.83	1.84
	2.09	1.97	1.83
	<u>2.15</u>	<u>1.97</u>	<u>1.84</u>
Average	2.00	1.99	1.97
Breton			
	<u>Site 1</u>	<u>Site 2</u>	<u>Site 3</u>
Depth	84"	102"	108"
	1.97	1.77	1.98
	1.78	1.73	1.84
	1.82	2.02	1.82
	2.22	1.80	1.82
	1.78	1.82	1.86
	1.77	1.75	1.81
	1.75	1.67	1.75
	1.74	1.73	1.76
	<u>1.70</u>	<u>1.71</u>	<u>1.71</u>
Average	1.84	1.78	1.81

TABLE II

Real specific gravity of Cooking Lake and Breton
grey wooded soil parent materials from three
locations as determined by the pycnometer method.

Cooking Lake			
	<u>Site 1</u>	<u>Site 2</u>	<u>Site 3</u>
Depth	80"	60"	72"
	2.61	2.66	2.73
	2.66	2.65	2.67
	<u>2.65</u>	<u>2.65</u>	<u>2.68</u>
Average	2.64	2.65	2.69

Breton			
	<u>Site 1</u>	<u>Site 2</u>	<u>Site 3</u>
Depth	84"	102"	108"
	2.68	2.71	2.71
	2.64	2.73	2.68
	<u>2.69</u>	<u>2.74</u>	<u>2.70</u>
Average	2.67	2.73	2.70

TABLE III

Per cent pore space of the Cooking Lake grey wooded soil parent material.

Location	Depth in inches	R.S.G.	A.S.G.	% Pore Space	Average
No. 1	80	2.64	2.00	24	
No. 2	60	2.65	1.99	25	
No. 3	72	2.69	1.97	<u>27</u>	25%

TABLE IV

Per cent pore space of the Breton grey wooded soil parent material.

Location	Depth in inches	R.S.G.	A.S.G.	% Pore Space	Average
No. 1	84	2.67	1.84	31	
No. 2	102	2.73	1.78	35	
No. 3	108	2.70	1.81	<u>33</u>	33%

Table V and Fig. 1 show the per cent sand in the Breton and Cooking Lake grey wooded soils. These are analyses of composite samples. The results were obtained by taking the average of duplicate analyses.

The following observations may be made:

1. The Cooking Lake soil has a higher total sand content in all horizons than the Breton soil.
2. In every horizon of the Cooking Lake soil, each size fraction in the sand content is generally greater.
3. In both soils the fine sand is the largest size fraction present.
4. The sand fraction in the Cooking Lake soil is largest in the A_2 horizon, decreases in the B_2 and B_{ca} , then increases and levels off in the P.M. In the Breton soils the B_2 has the least sand and the P.M. the most.

TABLE V

Per cent sand separates of Breton and Cooking Lake
grey wooded soils (composite samples) as determined
by the pipette method

Horizon	%Sand	%V.C.S.	%C.S.	%M.S.	%F.S.	%V.F.S.
C.L. A ₂	48.99	2.42	6.41	8.06	18.57	13.49
Br. "	32.64	0.78	2.70	4.75	12.88	11.52
C.L. B ₂	29.16	1.51	4.67	7.20	15.38	10.41
Br. "	27.07	0.34	1.97	3.89	11.88	9.04
C.L. Bca	39.20	1.87	5.18	6.86	14.72	10.57
Br. "	34.52	0.46	2.22	4.89	14.54	12.40
C.L. P.M.	42.12	1.65	5.10	7.80	16.27	11.29
Br. "	36.46	0.51	2.28	5.06	16.09	12.48

Figure 1.

Sand Separates
Cooking Lake and Breton
Grey Wooded Soils

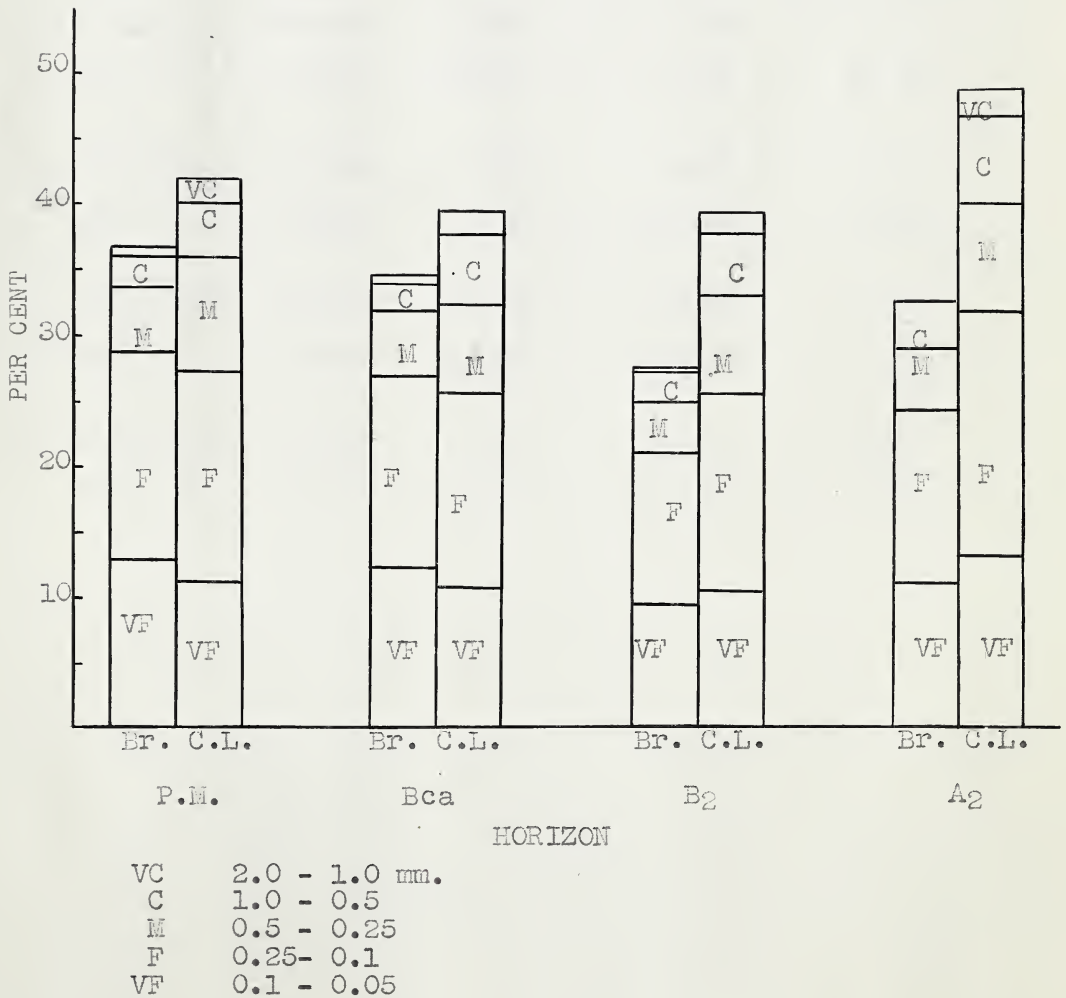


TABLE VI

Per cent silt separates of Breton and Cooking Lake grey wooded soils (composite samples) as determined by the pipette method

Horizon	% Silt	% C . Si.	% F. Si.	% V.F. Si.
C.L. A ₂	38.49	15.00	20.38	3.11
Br. "	54.55	22.41	28.89	3.25
C.L. B ₂	21.36	7.88	11.30	2.18
Br. "	32.18	9.24	19.93	3.02
C.L. Bca	28.68	12.26	14.35	2.06
Br. "	38.84	14.69	20.84	3.31
C.L. P.M.	28.68	9.97	14.94	3.77
Br. "	38.12	12.03	22.64	3.45

The per cent silt in the Cooking Lake and Breton soils is shown in Table VI and Fig. 2. The per cent coarse silt was determined by difference. In this work the various silt fractions are as follows: coarse silt - 50u to 20u, fine silt - 20 u to 5u and very fine silt - 5u to 2u.

The following observations may be made:

1. The total per cent silt is higher in the Breton soil in all horizons than the Cooking Lake soil.
2. The coarse silt and fine silt fractions are higher in all horizons in the Breton than in the Cooking Lake soil.
3. There is little difference in the very fine silt fraction in these soils.
4. The fine silt is the dominant fraction in both soils and in all horizons.
5. The coarse silt fraction is highest in the A₂ horizon, decreases in the B₂ horizon and increases slightly in the Bca and P.M. The total silt fraction shows the same trend.

Figure 2.

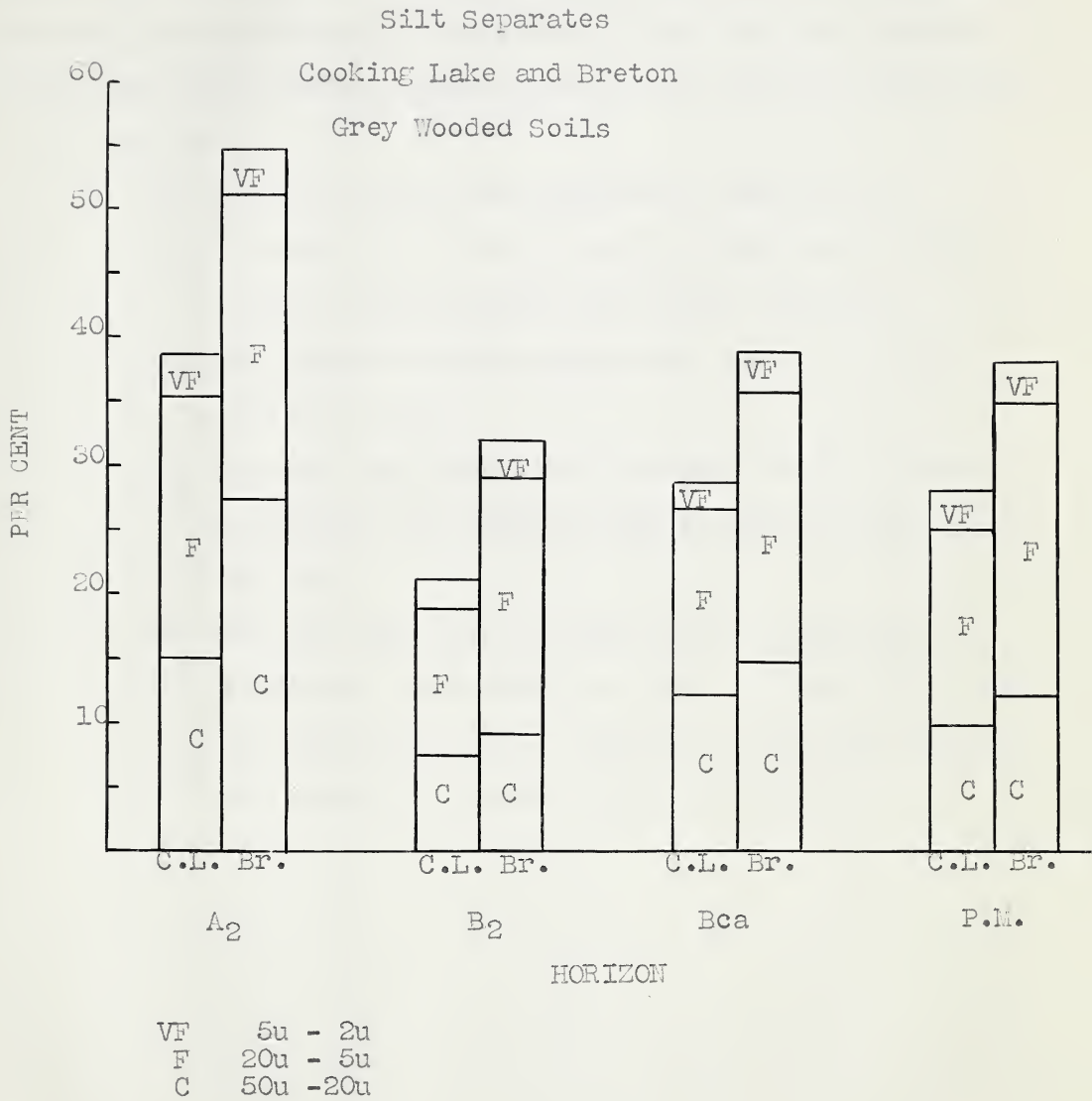


Table VII and Fig. 3 describe the clay content of the Cooking Lake and Breton soils. In this work, fraction size designations were as follows: coarse clay - 2μ to 0.2μ and fine clay - 0.2μ and less.

The results suggest the following observations:

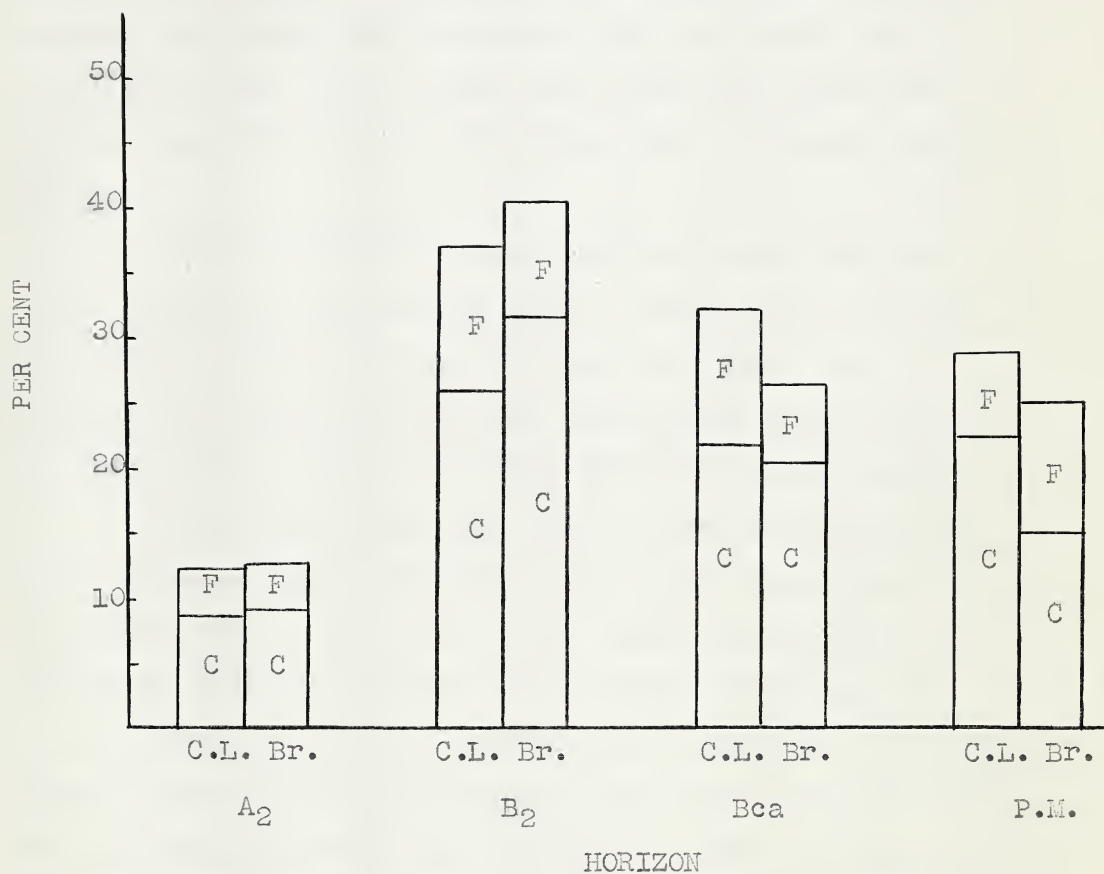
1. In both soils the A_2 horizons were considerably lower in clay content than other horizons.
2. The coarse clay is the dominant size fraction in both soils.
3. The per cent fine clay fractions is low in the A_2 horizon but remains fairly uniform in B_2 , B_{ca} and P.M.
4. The per cent clay content is low in the A_2 , increases considerably in the B_2 (from 12% to 40% in the Breton soil), decreases in the B_{ca} horizon and decreases slightly again in the P.M.

TABLE VII

Per cent clay separates of Breton and Cooking Lake
grey wooded soils (composite samples) as determined
by the pipette method

Horizon	Total	Coarse	Fine
C.L. A ₂	12.52	8.84	3.67
Br. "	12.81	9.14	3.68
C.L. B ₂	37.30	21.03	16.27
Br. "	40.76	26.82	13.94
C.L. Bca	32.13	21.70	10.43
Br. "	26.65	20.39	6.25
C.L. P.M.	29.11	22.64	6.47
Br. "	25.43	15.08	10.34

Figure 3.
Clay Separates
Cooking Lake and Breton
Grey Wooded Soils



F. 0.2u and less
C. 2u - 0.2u

Tables VIII and IX show the sand fractions present in Cooking Lake and Breton soils from three different sites and are included here for the purpose of showing the variations between the different locations. The composite samples previously discussed were made up of soil from these locations. Fig. 4 shows the total sand fractions present in each of these soils from three different sample areas.

The silt fractions and clay fractions from the three different locations of each of these soils is shown in tables X and XI, XII and XIII respectively. Fig. 5 depicts the total silt and clay fractions present in each of these soils, located in three different sample areas.

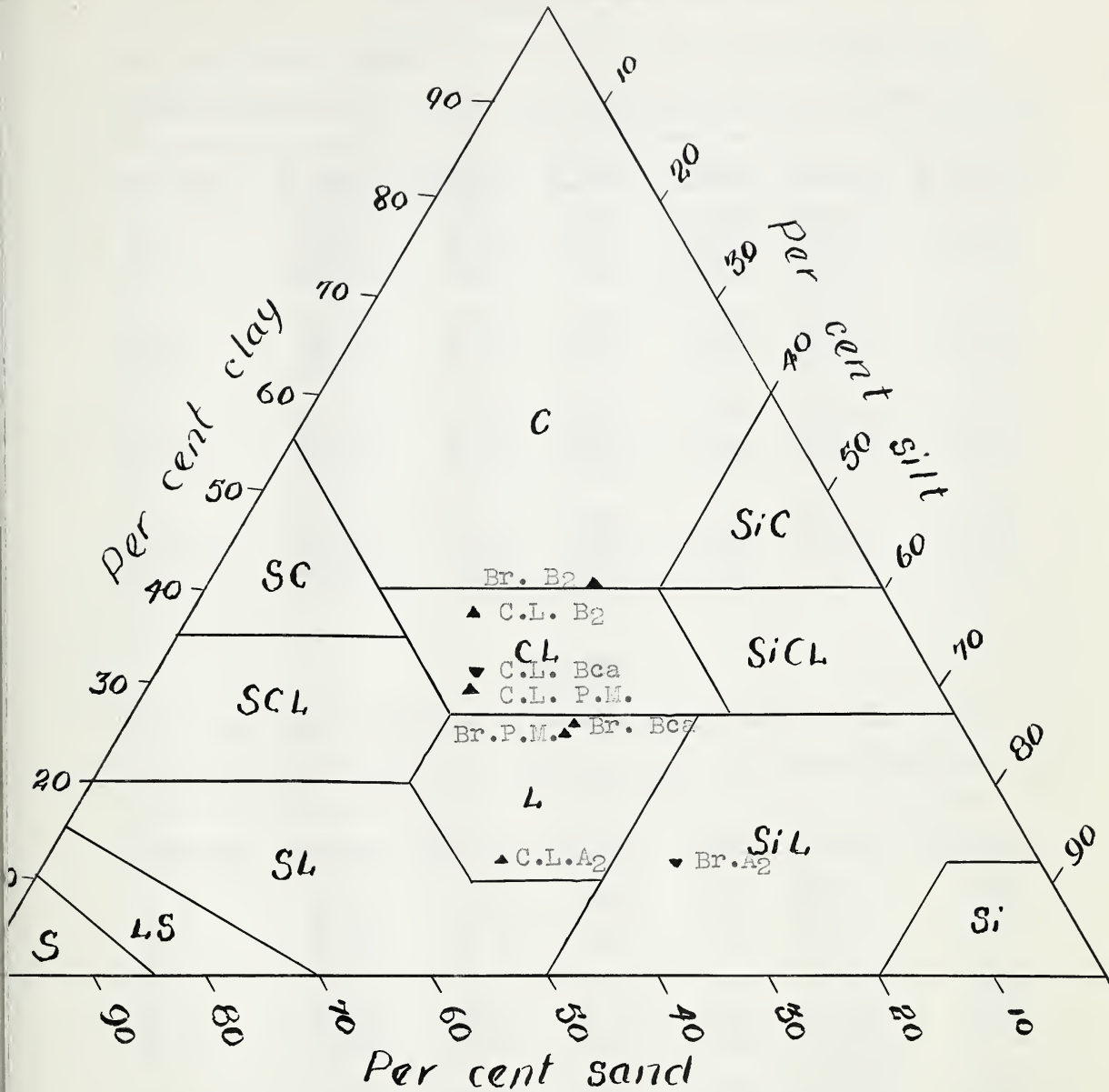
The above tables and figures show in general the same trends as were previously observed in discussing the composite samples of these soils. While samples from the different locations showed variations it would seem safe to conclude that the large differences between the composite samples were actually significant differences and not merely due to sampling error. Any differences which are shown in the composite sample are in most cases present in the individual samples which made up the composite sample.

Mechanical analyses show that there is little textural difference in these soils. In the U.S.D.A. guide for textural classification triangle (60) the soils were found to be as follows:

Horizon	Breton	Cooking Lake
A ₂	Silt loam	Loam
B ₂	Clay loam	Clay
Bca	Loam	Clay loam
P.M.	Loam	Clay loam

The greatest difference in the above textures was in the A₂ horizons. In the other horizons, the textures were very close, usually lying in adjacent positions and separated by the line which placed them in different textural classes.

Textures of Cooking Lake and Breton Soils



U. S. D. A. Guide for Textural Classification

Clay < 2 microns

TABLE VIII

Per cent sand separates of Cooking Lake grey wooded soils from Locations 1, 2 and 3 as determined by the pipette method

Horizon	% Sand	% V.C.S.	% C.S.	% M.S.	% F.S.	% V.F.S.
1	58.19	2.37	8.45	11.29	21.79	14.29
2 A ₂	45.93	2.35	5.12	6.83	16.88	14.75
3	54.18	1.47	6.65	10.15	21.04	14.89
1	37.08	1.48	4.25	6.49	14.23	10.63
2 B ₂	39.19	1.27	4.66	7.46	15.64	10.17
3	39.90	1.03	4.60	7.53	15.54	11.21
1	41.88	1.54	5.53	7.58	15.96	11.28
2 Bca	40.05	1.28	5.01	7.84	15.56	10.34
3	33.48	0.95	4.21	5.51	12.88	9.91
1	42.28	4.54	5.07	7.32	15.22	10.12
2 P.M.	42.74	1.28	5.52	7.55	16.21	12.17
3	43.00	1.47	5.09	7.51	16.59	12.34

TABLE IX

Per cent sand separates of Breton grey wooded soils from Locations 1, 2 and 3 as determined by the pipette method

Horizon	% Sand	% V.C.S.	% C.S.	% M.S.	% F.S.	% V.F.S.
1	33.27	1.15	3.55	5.44	13.32	9.80
2 A ₂	28.45	0.37	2.07	4.01	10.72	13.67
3	31.44	0.38	1.86	3.85	11.24	14.11
1	14.43	0.13	1.09	2.18	6.41	4.63
2 B ₂	25.89	0.53	1.87	3.93	11.39	8.16
3	36.44	0.36	2.02	4.68	15.84	13.54
1	35.09	0.50	2.39	5.00	14.75	12.44
2 Bca	34.66	0.32	2.32	4.90	14.35	12.77
3	34.58	0.61	2.15	4.90	15.24	11.77
1	64.32	0.44	3.83	9.90	30.82	19.32
2 P.M.	37.70	1.10	2.75	5.32	16.23	12.31
3	39.11	0.62	2.81	5.72	18.63	11.31

TABLE X

Per cent silt separates of Cooking Lake grey wooded soils
From Locations 1, 2 and 3 as determined by the pipette method

<u>Horizon</u>	<u>% Silt</u>	<u>% Cs. Si.</u>	<u>% F. Si.</u>	<u>% V.F. Si.</u>
1	35.94	16.59	16.00	3.35
2 A ₂	43.89	17.90	21.81	4.18
3	37.35	15.94	17.87	3.54
1	26.76	10.80	13.14	2.82
2 B ₂	29.23	7.14	16.42	5.67
3	24.70	10.75	12.99	0.96
1	27.89	11.84	13.63	2.42
2 Bca	28.61	13.39	15.22	0.00
3	30.06	10.75	18.72	0.59
1	26.31	3.26	21.02	2.03
2 P.M.	25.62	8.42	15.00	2.20
3	26.32	10.76	13.01	2.55

TABLE XI

Per cent silt separates of Breton grey wooded soils from
Locations 1, 2 and 3 as determined by the pipette method

<u>Horizon</u>	<u>% Silt</u>	<u>% Cs. Si.</u>	<u>% F. Si.</u>	<u>% V.F. Si.</u>
1	57.04	21.74	30.85	4.45
2 A ₂	59.71	24.74	31.23	3.74
3	60.02	26.89	30.14	2.99
1	29.46	8.13	18.09	3.24
2 B ₂	42.70	20.39	20.53	1.78
3	33.83	10.60	21.61	1.62
1	41.04	21.84	18.95	0.25
2 Bca	38.66	12.23	24.14	2.29
3	38.46	14.16	20.11	4.19
1	17.91	0.67	15.34	1.90
2 P.M.	37.75	13.57	20.68	3.50
3	34.60	6.78	26.79	1.03

TABLE XII

Per cent clay separates of Cooking Lake grey wooded soils from Locations 1, 2 and 3 as determined by the pipette method

<u>Horizon</u>	<u>Total % Clay</u>	<u>% Coarse</u>	<u>% Fine</u>
1	5.87	5.19	0.68
2 A ₂	10.18	9.50	0.68
3	8.47	6.68	1.79
1	36.16	17.08	19.08
2 B ₂	31.58	19.76	11.83
3	35.40	16.60	18.80
1	30.23	20.38	9.85
2 B _{ca}	31.34	20.40	10.94
3	36.46	26.29	10.17
1	31.41	19.29	12.12
2 P.M.	31.64	20.84	10.80

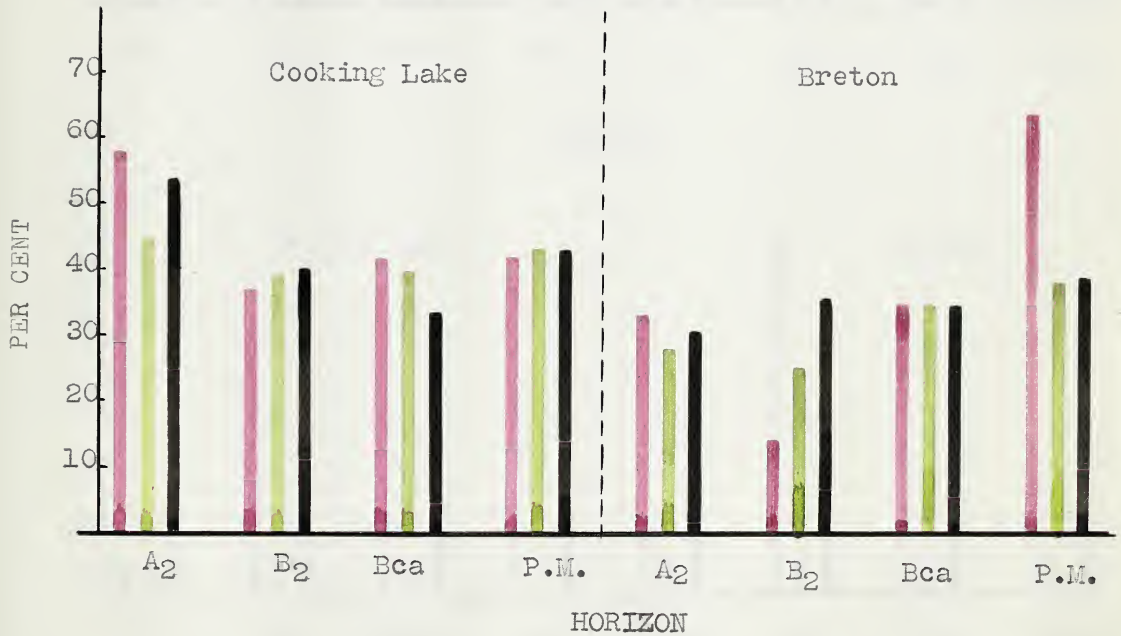
TABLE XIII

Per cent clay separates of Breton grey wooded soils from Locations 1, 2 and 3 as determined by the pipette method

<u>Horizon</u>	<u>Total % Clay</u>	<u>% Coarse</u>	<u>% Fine</u>
1	9.69	7.78	1.91
2 A ₂	11.84	8.78	3.06
3	8.54	7.42	1.12
1	56.11	43.70	12.41
2 B ₂	31.41	19.86	11.55
3	29.73	18.64	11.09
1	23.87	18.74	5.13
2 B _{ca}	26.68	20.78	5.90
3	26.96	21.21	5.75
1	17.77	14.02	3.75
2 P.M.	24.55	18.68	5.87
3	26.29	21.02	5.27

Figure 4.

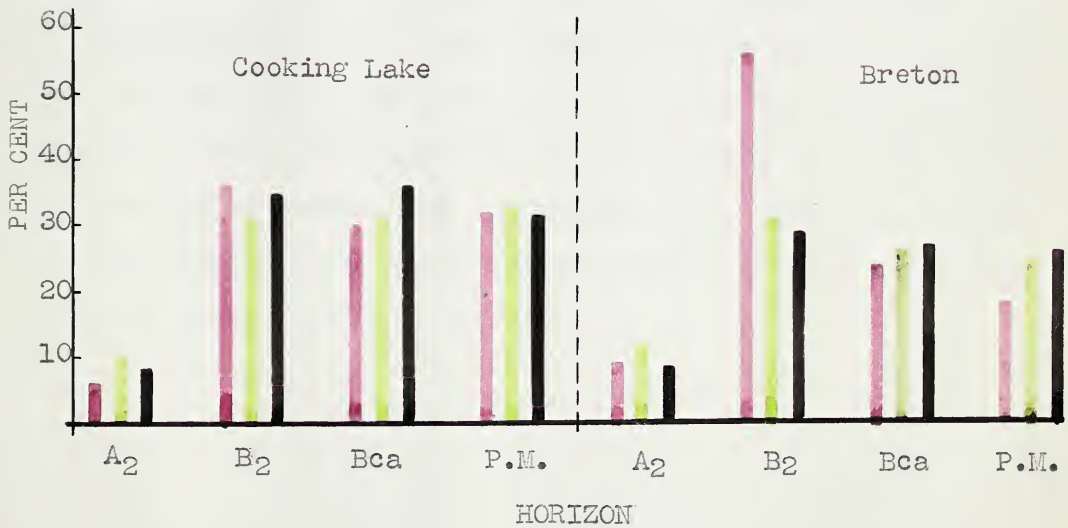
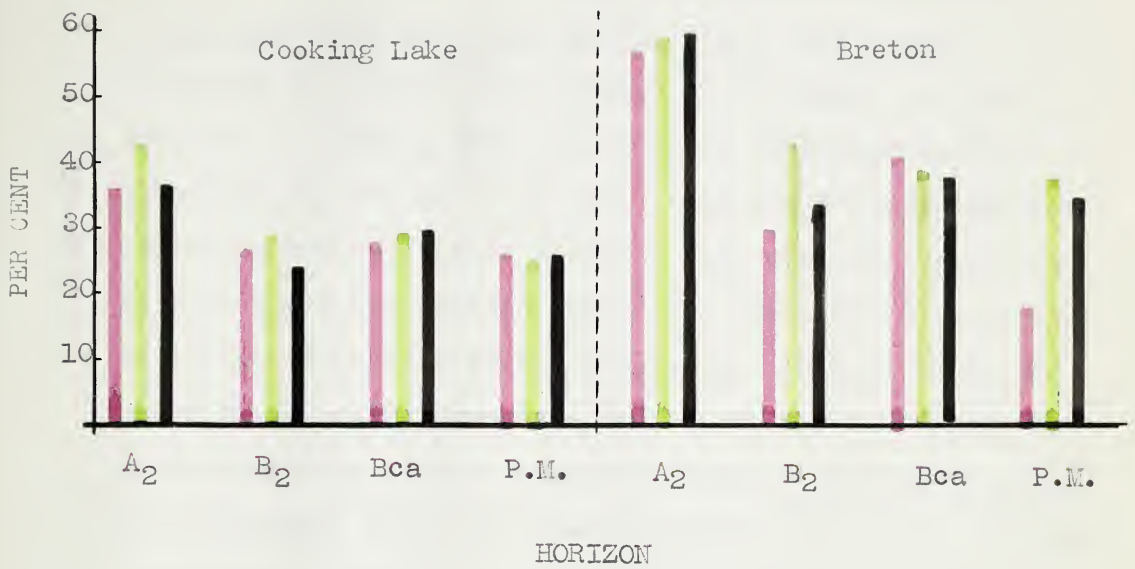
Sand separates as determined in three
locations on Cooking Lake and
Breton grey wooded soils



- Location No. 1
- Location No. 2
- Location No. 3

Figure 5.

Silt and Clay Separates as determined in three locations
on Cooking Lake and Breton grey wooded soils



Cooking Lake
 Location No. 1
 Location No. 2
 Location No. 3

Breton
 Location No. 1
 Location No. 2
 Location No. 3

The pF curves for the Cooking Lake and Breton parent materials are shown in Fig. (6). The curves represent the Breton P.M. sampled at locations one and two and the Cooking Lake P.M. sampled in duplicate at locations one and two. In both soils there was considerable variation in the tension at which they drained. There was as much variation between duplicates and between locations as there was between parent materials. In both soils the slope of the curve from zero tension to the flex point is steep with relatively little difference in degree of slope for the parent materials from different locations. This as pointed out by Bayer (op cit.) would indicate similar permeability rates. The volume of water removed from the soil core from zero tension to the flex point was small in both soils. The flex point of the curves was higher in all samples of Breton than in Cooking Lake. However, with so much variation it would not be logical to draw any sound conclusion from this difference.

Figure 6.

pF curves for Breton and Cooking
Lake parent materials

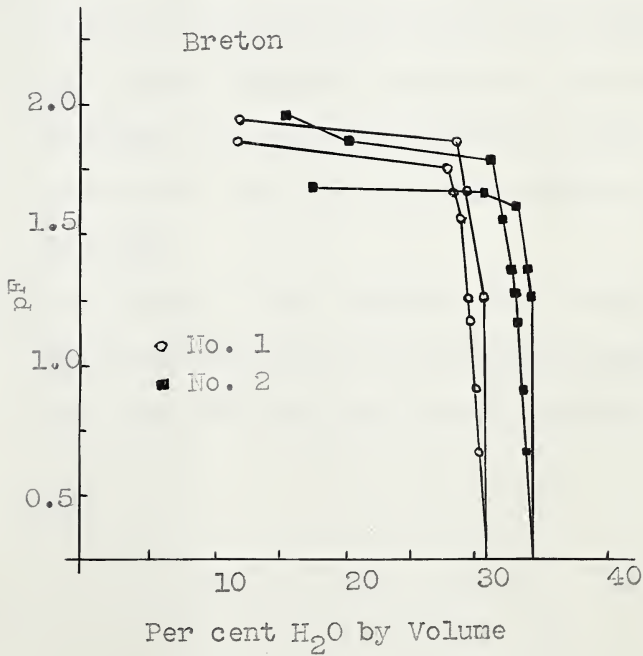
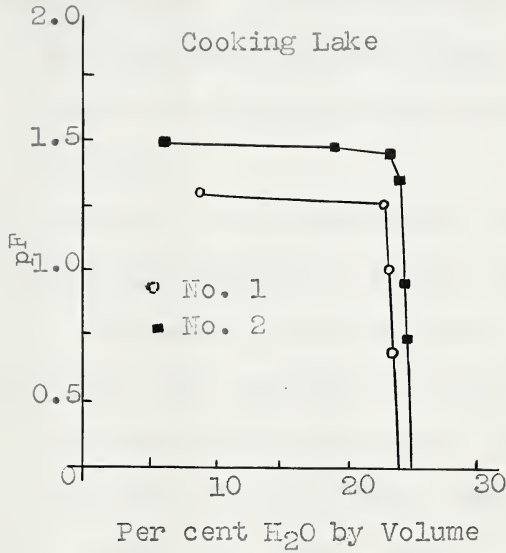


Table XIV shows the mineral count of the coarse sand (1.0 mm. to 0.5 mm.) and the fine sand (0.25 mm. to 0.1 mm.) from the Cooking Lake and Breton parent materials. Some general observations may be made regarding this table :-

1. The fine sand fraction shows a much greater number of minerals than does the coarse sand fraction.
2. There is little difference in the dominant minerals present in either soil, but there is a difference in the amounts present.
3. Of the more abundant minerals counted, olivine and andalusite are present in the Cooking Lake and absent in the Breton P.M.
4. In nearly all cases where the mineral is present in both the coarse and fine sand fractions, there is a sharp increase in minerals counted with a decrease in sand size fraction. This is most noticeable with the minerals amphibole and feldspars.
5. The mineral count suggests that there is more weathered material in the Breton parent material than the Cooking Lake parent material.

Minerals in sand fraction from parent materials of the Cooking Lake and Breton series

Sample	Number of grains examined	Opaque	Garnets	Micas	Chlorite	Amphiboles	Pyroxenes	Epidotes	Olivene	Analcite	Apatite	Collophane	Axinite	Galena	Spinel	Calcite	Aragonite	Feldspars	Quartz	Anhydrite	Ankerite	Dumortierite	Corundum	Barite	Andalusite	Dickite	Sericite	Haematite
Cooking Lake																												
Coarse Sand																												
< 2.95	49	18	4		2	1			1	3	2	14						1	1									
> 2.95	150	1	2	1					1	5		66	4	1				8	59									
Fine Sand																												
< 2.95	264	76	40	10	2	34	20	7	3					1	1	1	5			5	1	1		6	8	1		
> 2.95	292	1		10					7			1				21		135	97	3								
Breton																												
Coarse Sand																												
< 2.95	51	26										21*																
> 2.95	170	10		6	14							8				36	16	3	52									
Fine Sand																												
< 2.95	248	42	24	9		20	35	16										8	1		2		2	1				1
> 2.95	301	13		20												1		136 +	50	2	3						1	5
(30 altered)																												

Corundum	Barite	Andalusite	Dickite	Sericite	Haematite	Ilmenite	Gibbsite	Gypsum	Kyanite	Topaz	Spodumene	Chiaastolite	Tourmaline	Zircon	Cordierite	Diatoms	Very badly weathered or coated grains
	6	8	1			1	1		13		4		3		3	2	13
						1	1									2	12
																	4+
2	1				1	1			6	3		5	8	1	1	1	22
				1	5								2		9		60
																	29

*Numerous (hundreds) of tiny
collophane grains

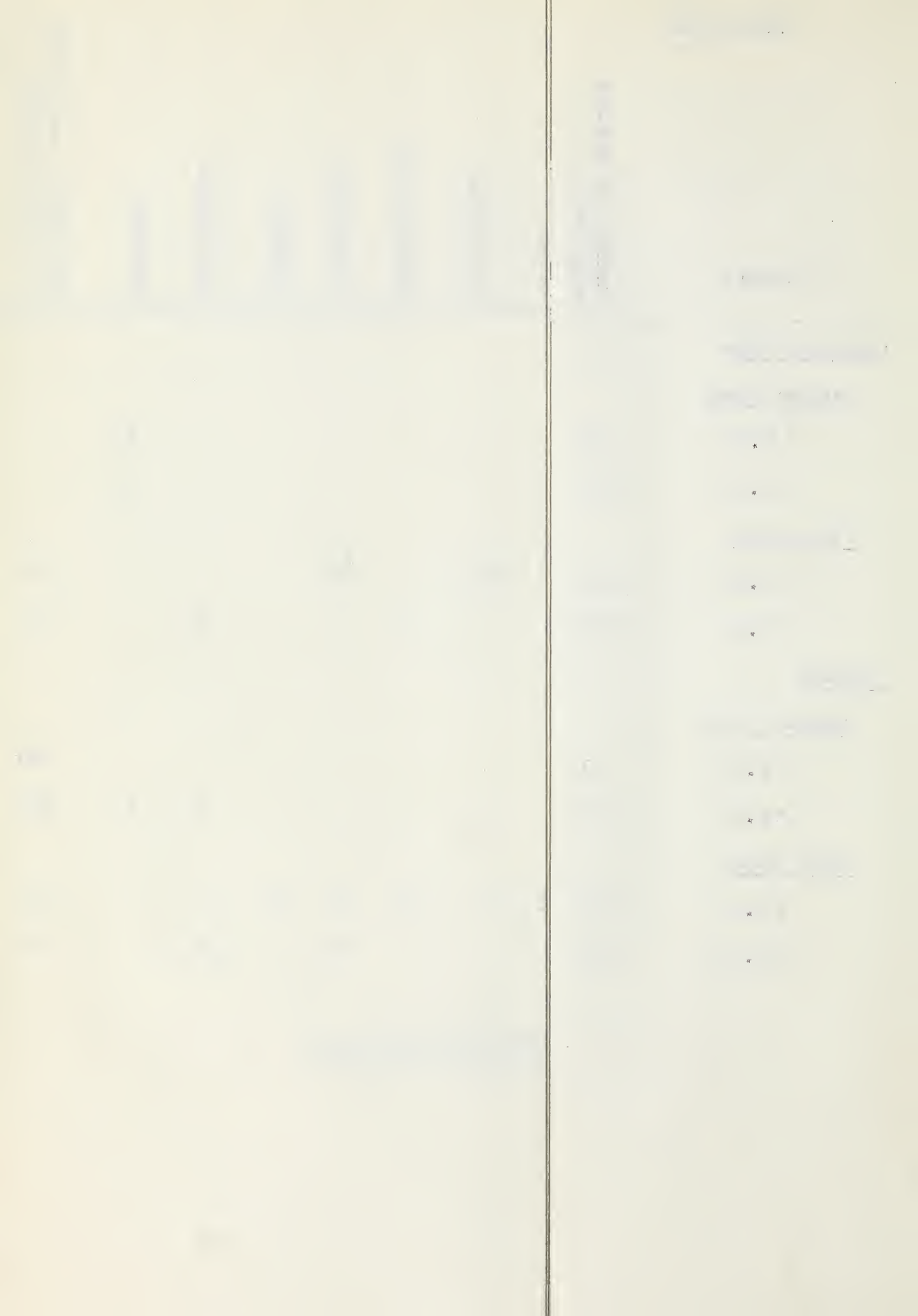


Table XV shows the minerals present in both of these parent materials in amounts in excess of one per cent. The minerals present in both parent materials in greatest quantity are feldspar, quartz and the opaque minerals. In the Cooking Lake material, these are followed by garnet and the amphiboles, while in the Breton P.M. pyroxene and mica are the next in order of dominance.

Table XVI shows the minerals present in the coarse sand fraction of Cooking Lake and Breton soils' parent materials in amounts in excess of one per cent. Collophane is the dominant mineral in both of these parent materials. In the Breton P.M. a lower percentage is noted than is actually present in this parent material. (see note table XIV). Cooking Lake P.M. is slightly higher in quartz content than Breton P.M. The percentage of opaque minerals, chlorite, calcite, argonite and mica is higher in Breton than Cooking Lake P.M. while per cent feldspars are higher in the Cooking Lake than the Breton P.M.

Fig. 7. shows the heavy minerals present in the fine sand fraction in excess of one per cent. The minerals having a specific gravity less than 2.95 are shown in Fig. 8. The latter shows that there is more feldspar and less quartz in the Breton than in the Cooking Lake P.M. There is very little calcite in this fine sand fraction of Breton P.M. About the same amount of micaceous material is present in the two fine sand fractions.

TABLE XV

Minerals present in the fine sand fractions of Cooking Lake and Breton grey wooded soil parent materials, expressed as a percentage of the total number of grains examined.

<u>Minerals</u>	<u>Cooking Lake</u>	<u>Breton</u>
Felspars	25.0	32.0
Quartz	18.0	9.3
Opaque	13.8	10.0
Garnet	7.1	4.3
Amphibole	6.1	3.6
Calcite	3.9	- -
Pyroxine	3.6	6.4
Mica	3.6	5.3
Kyanite	2.3	1.1
Olivine	1.8	- -
Andalusite	1.4	- -
Anhydrite	1.4	- -
Epidote	1.3	2.9
Barite	1.1	- -
Tourmaline	- -	1.8
Cordierite	- -	1.6
Haematite	- -	1.1
Weathered and coated material	4.5	16.2

The following minerals were also recognized in amounts less than one per cent of the total grains counted.

Cooking Lake parent materials:

Chloritic material, collophane, galena, spinel, argonite, ankerite, dumortierite, dickite, gibbsite, gypsum, spodumene, tourmaline and cordierite.

Breton parent materials:

Analcite, calcite, anhydrite, ankerite, corundum, barite, sericite, illmenite, topaz, chiastolite and zircon.

TABLE XVI

Minerals present in the coarse sand fraction of the Cooking Lake and Breton grey wooded soils parent materials, expressed as a percentage of the total number of grains counted.

<u>Minerals</u>	<u>Cooking Lake</u>	<u>Breton</u>
Collophane	40.0	13.0
Quartz	30.0	23.0
Opaque	9.5	16.0
Felspar	4.5	1.4
Analcite	4.0	- -
Axinite	2.0	- -
Garnet	3.0	- -
Chlorite	1.0	6.3
Olivine	1.0	- -
Apatite	1.0	- -
Calcite	- -	16.0
Argonite	- -	7.2
Mica	- -	2.7

The following minerals were also identified in amounts less than one per cent of the total grains counted.

Cooking Lake parent materials:

Mica and amphibole.

Breton parent materials:

Analcite and cordierite.

Figure 7.

Cooking Lake and Breton grey wooded
parent material mineral content
of the fine sand (0.25 mm. to 0.1 mm.)

specific gravity > 2.95

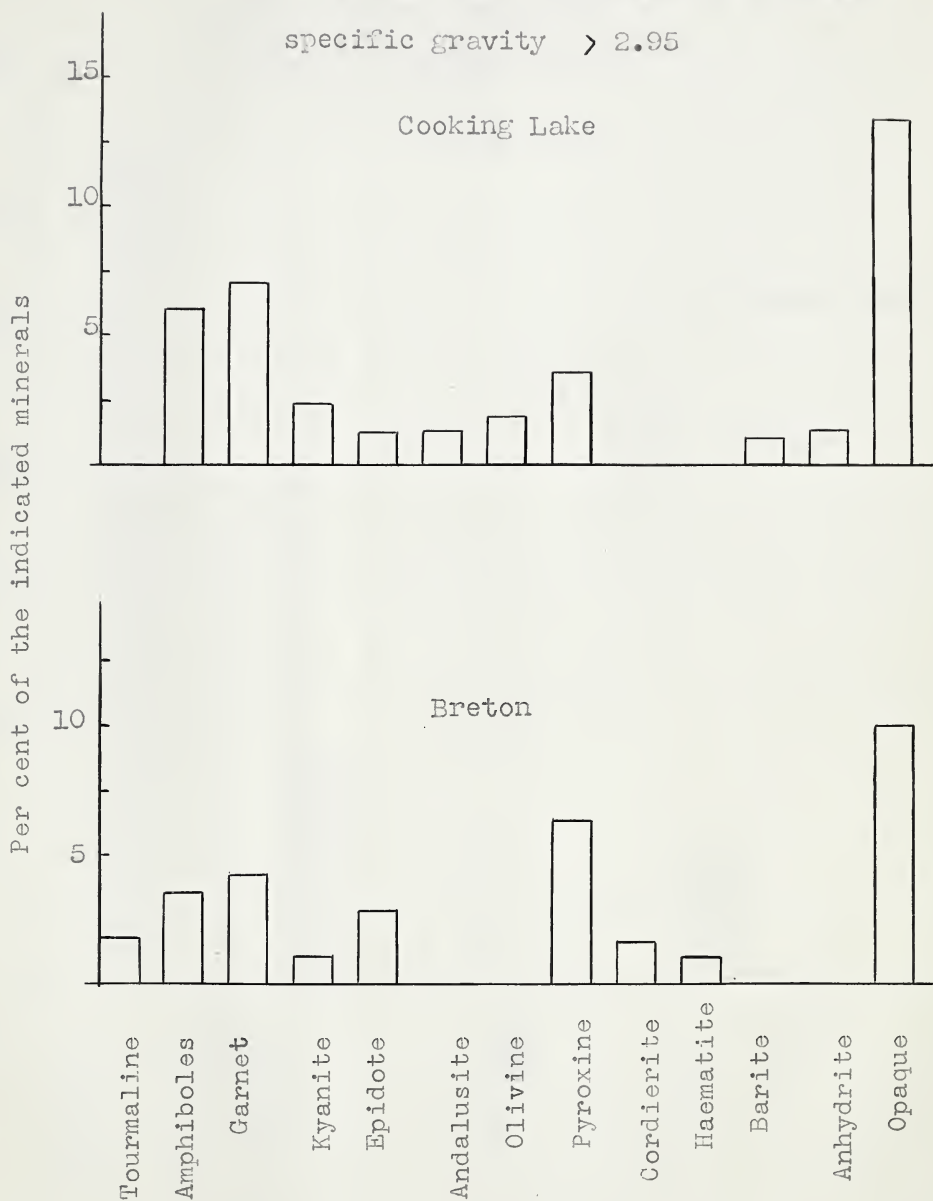
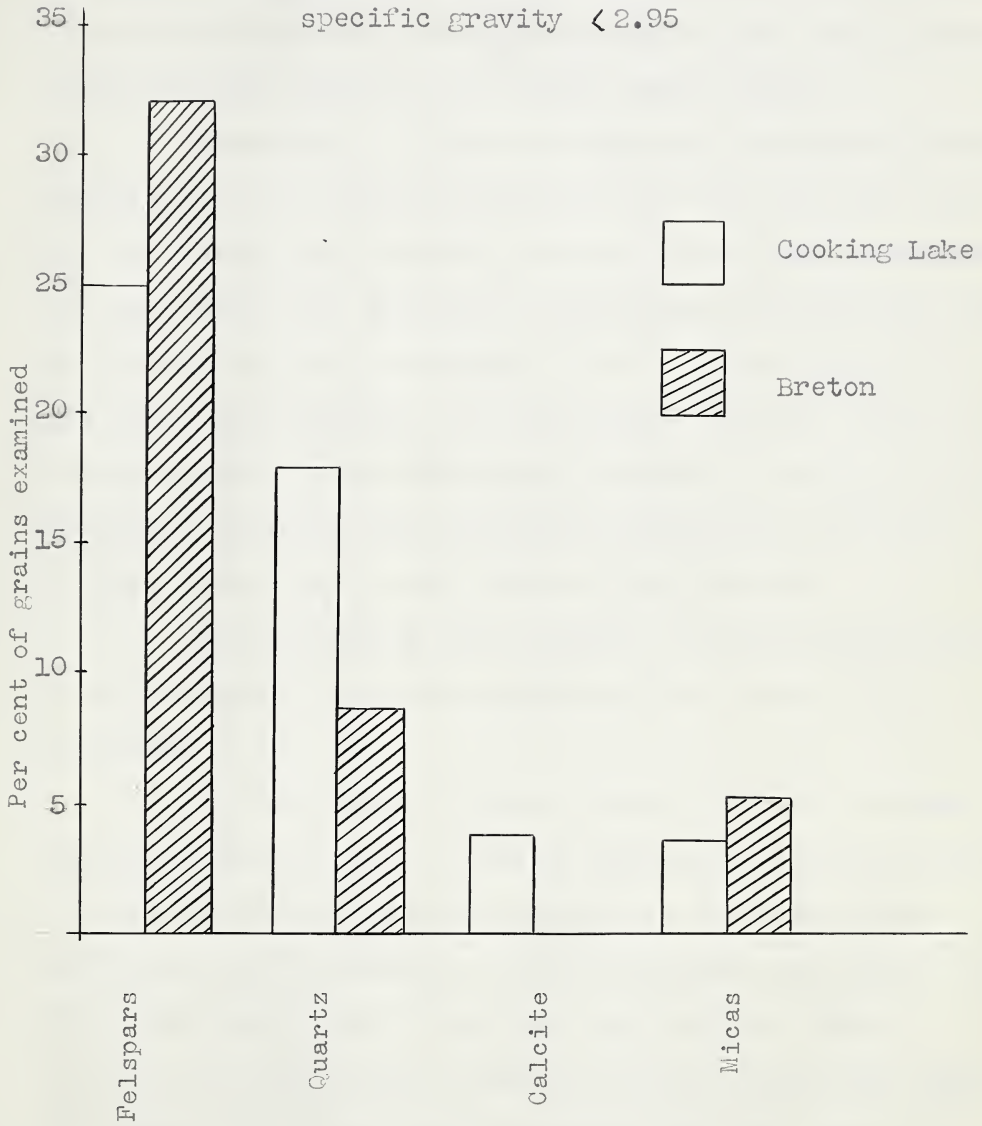


Figure 8.

Cooking Lake and Breton grey wooded parent
material mineral content of the fine
sand (0.25 mm. to 0.1 mm.)

specific gravity < 2.95



Tables XVII and XVIII show the minerals present in the coarse and fine clay fractions of the two parent materials. The table indicates that the dominant clay minerals in the parent materials are the montmorillonite group and illite, with kaolinite occurring to a much lesser degree.

Generally, in both of these soils montmorillonite appears to be in largest quantities in the fine clay fraction. In the Cooking Lake profile, illite is in larger quantities in the coarse clay fraction in the A₂ and B₂ horizons, while in the Bca and P.M. horizons, it is in largest quantities in the fine clay fraction. In the Breton profile, illite is in larger amounts in the fine clay fractions of the A₂ and B₂ horizons, while in the Bca and P.M. horizons, it is in largest quantities in the coarse clay fraction.

In the Cooking Lake profile, montmorillonite appears to be present in greater quantities than illite in all horizons.

In the Breton profile, illite generally exceeds montmorillonite in the A₂ and B₂ horizons, while the reverse is true of the Bca and P.M. horizons. There is little difference in the amount of montmorillonite and illite in the parent materials of both of these soils. However, considerable differences exist in the A₂, B₂ and Bca horizons. The kaolinite present in the Cooking Lake soil shows a tendency to increase with depth, reaching a maximum in the

parent material. In the Breton profile, kaolinite is higher in the A_2 horizon than the B_2 or Bca and in amounts similar to the A_2 horizon in the P.M.

Felspar present in the clay fraction remains fairly constant in all horizons in the Breton profile, while in the Cooking Lake profile, there is a definite tendency for the felspar to increase with depth.

In both profiles quartz appears to be associated with the coarse clay fraction. Quartz appears in similar quantities in the A_2 and P.M. horizons and in smaller quantities in the B_2 and Bca horizons.

The largest concentration of chlorites appeared in the fine clay fraction of the B_2 horizon and the coarse clay fraction of the Bca horizon of the Cooking Lake soils. The parent material of this soil showed the least accumulation of chlorites of the horizons examined. In the Breton profile, chlorites were concentrated to the greatest extent in the coarse clay of the A_2 horizon and the fine clay of the B_2 horizon. In the remaining horizons of this soil, chlorites appeared in similar amounts in all size fractions with the exception of the coarse clay in the parent material where only a trace of this mineral was reported.

Muscovite was found in similar amounts in both clay fractions of all horizons of the Cooking Lake soil, with the exception of the coarse clay of the P.M. where greater

concentrations were found. Muscovite in the Breton profile in greatest concentrations was confined to the coarse clay of the B₂ horizon and both clay fractions of the Bca horizon.

Apatite was present in all horizons of the Cooking Lake profile, while in the Breton profile it is present only in very small amounts in the B₂, Bca and P.M. horizons.

Gypsum was found in largest accumulation in the fine clay fraction of the Bca horizon in the Cooking Lake soils. This mineral was absent in all horizons of the Breton soils.

The remaining minerals reported in these two tables, are not present in sufficient amounts to compare differences in the two soils, or differences in horizons of either soil.

The method of determination was qualitative and comparison of minerals present in minor amounts without further analyses would probably be in error. However, it is worth noting that the minerals reported present in minor amounts are generally concentrated in the upper horizons of these two soils.

On ignition of the clay samples of these two soils, the Cooking Lake sample gave a white to creamy residue, showing a lack of iron compounds, while the Breton samples were quite red, indicating a high percentage of iron bearing compounds. The iron bearing minerals shown in the table do not indicate any reason for this difference.


Table XVII

Group 2

Minerals in the clay fractions from Cooking Lake profile

Horizons	Group 1										Magnesite	Talc	Sericite	Sepiolite	Antigorite + Chrysotile	Diaspore	Gypsum	Boehmite	Bayerite	Apatite	Pyrophyllite	Aragonite	Calcite	Mullite	Corrundum(Al2O3)	Fe2O3.H2O	Goethite	Chamosite	Haematite
	Montmorillonoids	Illite	Feldspar	Chlorites(Fe)	Quartz	H-Micas	Kaolinite (M-Halloysite)	Vermiculite	Muscovite																				
15. A2 <0.2u	40	6	5	6		Pr.	Tr.	Pr.	Tr.		2-3	Pr. ++		Tr.					Tr.	2+	Tr.	Tr.			Tr.		Tr.	Tr.	
16.A2(2-0.2)u	30	12	8	Tr.	23	Pr.	3		Tr.		Tr.	Pr. +++	Pr.		Pr.		Pr.		5	Tr.		Tr.		Tr.					
11.B2 <0.2u	30	17	5	16		Pr.	Tr.	Tr.	Tr.	Tr.	2+	Pr. ++	Pr.	Tr.	Pr.	Tr.	Pr.		2	Pr.		Tr.		Tr.			Pr.	Tr.	
12.B2(2-0.2)u	40	24	7	Tr.	13	Pr.	5		Tr.			Pr.	Tr.	Tr.	Tr.					Tr.	Tr.	Tr.		Tr.					
7.Bca <0.2u	40	27	8	7	Tr.		Tr.		Tr.				Pr. ++			5			2						Tr.	Tr.	2+		
8.Bca(2-0.2)u	40	24	9	10	11		2		2+							Pr.													
3.P.M. <0.2u	45	28	17	Tr.	5		5													Tr.	Tr.								
4.P.M. (2-0.2)u	20	21	18	Tr.	20		5.5		5		Tr.								5	Tr.		Tr.							

Group 2

 Fe ₂ O ₃ .H ₂ O	Goethite	Chamosite	Haematite	Amphibole	Palygorskite	Lepidocrocite	Biotite	Notes
Tr.	Tr.	Tr.	Pr.					Group 1 contains no iron compounds with the exception of the chlorite group.
			Pr.					
	Pr.	Tr.	Pr.	Tr.	Tr.			Group 2 contains only iron-bearing compounds.
				Tr.				Tr. = Trace - very small amounts, probably less than 1%.
Tr.	Tr.	2+	Pr.					Pr. = Present - compounds for which no pure standards were available and may represent amounts varying from less than 1% to 10%.
			Pr.					

Group 1.

Minerals in the clay fractions from Breton profile

Horizons	Montmorillonoids	Illite	Feldspar	Chlorites	Quartz	HOMicas	Kaolinite (M-Halloysite)	Vermiculite	Muscovite	Magnesite	Talc	Sericite	Sepiolite	Antigorite & Chrysotile	Diaspore	Gypsum	Boehmite	Bayerite	Apatite	Pyrophyllite	Aragonite	Calcite	Mullite	Corundum (Al ₂ O ₃)	Fe ₂ O ₃ . H ₂ O	Goethite
13. A ₂ <0.2u	20	22	8	Tr.		Pr.	2+		Tr.		Tr.	Pr. ++	Tr.	Pr.	Pr.					Tr.	Tr.	Tr.		Pr.		
14. A ₂ (2-0.2)u	15	12	9	12	17				Tr+			Pr.		Pr.	Pr.		Tr.	Pr.				Tr.	2	Pr.		Pr.
9. B ₂ <0.2u	20	30	6	11			Tr.		Tr.		Tr.		Pr.		2				2	2+		2	Pr.			Pr.
10. B ₂ (2-0.2)u	15	24	7	Tr.	13	Pr.	Tr.		5		Tr.						Tr.					2	Pr.			
5. B _{ca} <0.2u	45	19	6	5		Pr.		Tr.	2-3		5		Pr.		Tr.			Pr.					Tr.			Pr.
6. B _{ca} (2-0.2)u	15	27	8	9	8.4		Tr.	Tr.	5				Pr.		Tr.				Tr.	Tr.						
1. P.M. <0.2u	50	24	7	7			2+		Tr.								Tr.									
2. P.M.(2-0.2)u	20	25	9	Tr.	14				2			Pr.	Pr.		Pr.				Tr.	Tr.		Tr.				

Group 2.

 β Fe₂O₃ · H₂O

Goethite

Chamosite

Haematite

Amphibole

Palygorskite

Lepidocrocite

Biotite

Notes

Pr.

Tr.

Pr.

Tr.

Tr.

Pr.

Group 1 contains no iron compounds with the exception of the chlorite group.

Pr.

Pr.

Tr.

Tr.

Pr.

Group 2 contains only iron-bearing compounds.

Pr.

Pr.

Pr.

1

Tr.

Pr.

Tr. = Trace - very small amounts, probably less than 1%.

Pr. Pr.

Pr.

Pr. = Present - compounds for which no pure standards were available and may represent amounts varying from less than 1% up to 10%.

Pr.

Pr.

Tr.

<p>1. The first part of the document is a list of names and addresses of the members of the committee.</p> <p>2. The second part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p> <p>3. The third part is a list of the names of the members of the committee who have been elected to the office of the Treasurer.</p> <p>4. The fourth part is a list of the names of the members of the committee who have been elected to the office of the Chairman.</p> <p>5. The fifth part is a list of the names of the members of the committee who have been elected to the office of the Vice-Chairman.</p> <p>6. The sixth part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p> <p>7. The seventh part is a list of the names of the members of the committee who have been elected to the office of the Treasurer.</p> <p>8. The eighth part is a list of the names of the members of the committee who have been elected to the office of the Chairman.</p> <p>9. The ninth part is a list of the names of the members of the committee who have been elected to the office of the Vice-Chairman.</p> <p>10. The tenth part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p>	<p>1. The first part of the document is a list of names and addresses of the members of the committee.</p> <p>2. The second part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p> <p>3. The third part is a list of the names of the members of the committee who have been elected to the office of the Treasurer.</p> <p>4. The fourth part is a list of the names of the members of the committee who have been elected to the office of the Chairman.</p> <p>5. The fifth part is a list of the names of the members of the committee who have been elected to the office of the Vice-Chairman.</p> <p>6. The sixth part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p> <p>7. The seventh part is a list of the names of the members of the committee who have been elected to the office of the Treasurer.</p> <p>8. The eighth part is a list of the names of the members of the committee who have been elected to the office of the Chairman.</p> <p>9. The ninth part is a list of the names of the members of the committee who have been elected to the office of the Vice-Chairman.</p> <p>10. The tenth part is a list of the names of the members of the committee who have been elected to the office of the Secretary.</p>

DISCUSSION OF RESULTS

The Breton parent material has a slightly higher real specific gravity than the Cooking Lake parent material. However, the variation of both soils is within narrow limits, approximately 2.6 to 2.7. The narrow limits of these results are worthy of note since it was found in the mineralogical analysis that feldspar and quartz make up the majority of the minerals present in the parent materials investigated.

The Cooking Lake parent material is shown to have a higher apparent specific gravity or volume weight than the Breton parent material in each of the sample locations. The volume weight differs from specific gravity in that it compares the weight of the dry soil to the weight of water of the same total volume, that is, the space usually filled by soil particles, soil air, and soil water. It might be concluded therefore, that the Cooking Lake P.M. is compacted to a greater degree than the Breton P.M. Lyon and Buckman (op cit.) state that very compact soils regardless of texture may have volume weights in the neighborhood of 2.0. Cooking Lake P.M. as observed in the field, does appear to be more compact than Breton P.M., a fact which was taken into consideration when these soils were classified.

The amount of pore space in a soil is determined by its structural conditions, that is, by the inter-related influences of texture, compaction and aggregation. Lyon and Buckman state that in a compact subsoil the pore space may be

as low as 25 or 30 per cent. In the Cooking Lake and Breton soils, the parent materials approximated these values, Cooking Lake being 25 per cent and Breton 33 per cent pore space. These values for pore space represent the volume percentage, but do not characterize the size of the pores. This indicates that the Cooking Lake P.M. is compacted to a greater degree than the Breton P.M. and has a lower per cent pore space, as would be expected.

The mechanical analyses of these soils revealed little differences in the horizons examined, with the exception of the A₂ horizons, where the Breton soil was found to have a higher percentage of silt and a lower percentage of sand than the Cooking Lake soil.

The B₂ horizons in both of these soils were shown to have a higher percentage of clay than all other horizons. The A₂ horizon was shown to have a very low percentage of clay present, while the clay content of the B_{Ca} and P.M. horizons were about the same in both soils. The high percentage of clay in the B₂ horizons suggest that eluviation of the A₂ horizon has taken place with a subsequent accumulation of the clay in the B₂ horizon; since the clay present in the B₂ is in greater quantities than could have been inherited from the parent material. This is characteristic of the grey wooded process.

The variation in the curves obtained for the Breton P.M. and Cooking Lake P.M. sampled in the same locations indicate that to ascertain any degree of accuracy for pF values of these soils a far greater number of cores would be needed. However, the curves do indicate certain characteristics of these parent materials which have been observed under field and previous laboratory investigations. The steep slope of the curves for both soils indicate a uniformity in the size of the pores.

Volume weight determinations indicated that both of these soils were compressed to a considerable degree. It is obvious that compaction tends to decrease the amount and size of the larger pores in clay soils. The small amount of water withdrawn from zero tension to the flex point of the curves might indicate a system of small pores which require a high tension to move a small volume of water through them. The higher flex point of the curves for Breton P.M. suggest that the pore size of this P.M. is smaller than that of the Cooking Lake P.M. However, the variation in the curves of both soils does not allow us to conclude whether this is actually the situation or not.

The mechanical analyses of individual soils taken in the different sample areas indicate that the differences found between the composite samples were real differences since they were much larger than the differences between samples from the same area.

The mineralogical analyses of the coarse and fine sand fractions of the parent materials of these soils indicated

that there is little difference in the kind of minerals present, but considerable differences are apparent in the quantities in each soil. These results indicate that there is no mineral or minerals present in sufficient quantities in either parent material to differentiate them on a mineralogical basis.

However, it should be noted that olivine, andalusite, barite and anhydrite were present in the Cooking Lake material in excess of 1 per cent and absent in the Breton parent material. Similarly tourmaline, cordierite and haematite were present in the Breton parent material and absent in the Cooking Lake parent material. These differences in mineral content could not be interpreted as being characteristic of either soil unless they were also shown to be present on examination of the very fine sand fraction (0.1 mm. to 0.05 mm.). It is in this fraction that the greatest variety of mineral content would most likely be present.

Sanderson (56) examining thin sections, found the Edmonton sandstone to be characterized by a preponderance of feldspar grains over quartz. One sample of Paskapoo sandstone was examined and had a much higher percentage of quartz than feldspar. In each sample he noted that a high percentage of the feldspar present was weathered. The dominant minerals in both of the fine sand fractions are the feldspars, followed by quartz and opaques. The feldspars are readily weathered

and this is observed by their high concentration in the fine sand fraction and low concentration in the coarse sand; while quartz, which is highly resistant to weathering, occurs in considerable amounts in both the coarse and fine sand fractions. The mineral collophane is confined to the coarse sand fraction in considerable amounts suggesting that under pedogenic processes the mineral is resistant to weathering.

The high amounts of weathered material, weathered feldspars and the possible presence of broken down collophane in the Breton parent materials suggest that this parent material is weathered to a greater degree than is the Cooking Lake parent material.

Workers in the United States, Coleman and Jackson (op cit.), Caldwell (op cit.) found montmorillonite to be the dominant soil clay mineral. Coleman and Jackson reported kaolinite to be predominant only in a few highly weathered soils in south eastern United States.

X-ray analyses of the Breton and Cooking Lake soils showed the montmorillonoids and illite to be dominant clay minerals in these soils. Kaolinite was noted only in small amounts. There is no apparent difference in the content of the montmorillonites in the different horizons of both soils. In the Breton soil the increase in illite in the B₂ horizon over the amount present in the P.M. is possibly due to leached

material from the A_2 horizon accumulating in the B_2 horizon of this soil. There is a greater concentration of illite in the B_2 than in the A_2 horizon of the Cooking Lake soil. However, the amount of illite in the B_2 horizon does not exceed that present in the P.M. and is therefore probably inherited from the parent material. Kaolinite, while present in the A_2 horizons of both of these soils, is also present in the parent materials. It therefore seems unlikely that the small amounts present in the A_2 horizon could have resulted from pedogenic processes. It is doubtful whether the platy structure described by Peterson (op cit.) and found in the A_2 horizons of these soils could be due to the small amounts of kaolinite present.

The relatively high percentage of feldspar present in both clay fractions indicates the degree of weathering of this mineral in these soils. The increase in this mineral with depth in the Cooking Lake soil suggests either a decreased weathering with depth, or an intense weathering in the upper horizon and subsequent accumulation in the lower horizons.

In view of Sanderson's (op cit.) findings, it is also possible that considerable weathered feldspar was present in the parent materials of these soils when they were deposited and weathering has continued. The relative abundance of minerals of clay fraction size concentrated in

the A₂ and B₂ horizons of both of these soils suggest that in these horizons are accumulated the mineral products of the soil pedogenic processes. The physical analyses carried out show that the only appreciable difference in these parent materials is the higher volume weight of the Cooking Lake soil. This is probably due to greater compaction of this material. The mineralogical analyses, both petrographic and x-ray, showed little difference between the two soil parent materials and although the mineralogical analyses were qualitative in nature there is evidence to suggest doubt as to whether or not these two soils should be separated into different series.

SUMMARY

1. The physical and mineralogical characteristics of the Breton and Cooking Lake grey wooded soils have been investigated.
2. There appears to be little difference in the physical characteristics of the parent materials examined. Cooking Lake parent material is thought to have been compacted to a greater degree than Breton parent material.
3. pF curves determined on Cooking Lake and Breton soils suggest that both of these soils are uniform in size of pores.
4. pF values indicated that both soils were compact, with a probable low percolation rate.
5. The variation in the results of pF determination indicate that to interpret results of this nature with any degree of accuracy large numbers of cores must be used.
6. Petrographic examination of the coarse and fine sand fraction of the parent materials did not indicate any characteristic mineral in large quantities that could be associated with either parent material.
7. X-ray analyses showed the dominant clay minerals to be montmorillonite and illite in these soils.
8. The higher percentage of illite present in the B₂

horizon of the Breton soil indicated that translocation of the mineral had taken place from the A₂ horizon.

9. There was no apparent difference in the dominant clay minerals in the parent materials of these soils.
10. This investigation suggests that the differentiation of the Breton and Cooking Lake soils into different series on the basis of differences in their parent materials is not justified.

BIBLIOGRAPHY

1. ALEXANDER, L.T., HENDRICKS, S.B., NELSON, R.A. Minerals present in soil colloids: II Estimation in some representative samples. Soil Sci. 48: 273-279. 1939.
2. ALLAN, J.A. Geology. Res. Coun. of Alberta Rpt. 34. 1934.
3. ALLEN, V.T. Petrographic studies bearing on the genesis and morphology of Illinois soils. Proc. 2nd Inter. Cong. Soil Sci. 5:113-117. 1932.
4. ATKINSON, H.J., RICE, H.M. Soil mineralogy. Chemistry in Canada. 2: 29-33. 1950.
5. _____ Soil mineralogy II preliminary results in mineralogical investigations of Canadian soils. Scientific contribution. 18c. Div. of Chem. Sci. Service. Ottawa. 1950.
6. BAVER, L.D. Soil physics, pp. 1-398. John Wiley and Sons, Inc., New York. 1948.
7. BIDWELL, O.W., PAGE, J.B. The effect of weathering on the clay mineral composition of soils in the Miami catena. Soil Sci. Soc. Am. Proc. 15: 314-318. 1950.
8. BOWSER, W.E., ERDMAN, R.L., WYATT, F.A., NEWTON, J.D. Soil survey of Peace Hills sheet. Univ. of Alberta. Bull. 48. 1947.
9. _____, PETERS, T.W. Soil survey of Red Deer sheet. Univ. of Alberta. Bull. 51. 1951.
10. BROWN, A.L., CALDWELL, A.C. Clay mineral content of the colloidal material extracted from a solodi soil profile. Soil Sci. Soc. Am. Proc. 11: 213-215. 1946.
11. BUCKHAMMAN, W.H., HAM, W.E., Preliminary investigation of heavy mineral criteria as an aid in the identification of certain soils in Oklahoma. Soil Sci. Soc. Am. Proc. 6: 63-67. 1941.

12. BUEHLER, T.F., ROBINSON, D.O., DENING, J.M. The mineral composition of the colloidal fraction of some south western soils in relation to field behavior. Soil Sci. Soc. Am. Proc. 13: 157-165. 1948.
13. CADDY, J.G. Soil analyses significant in forest soil investigations and methods of determinations: 3. Some mineralogical characteristics of podzol and brown podzolic forest soils. Soil Sci. Soc. Am. Proc. 5: 352-354. 1940.
14. CARROLL, D. Heavy mineral assemblages of soils from the Gold Fields of western Australia. Geo. Mag. 73: 503-511. 1936.
15. COLEMAN, R., JACKSON, M.S. Mineral composition of the clay fraction of several coastal plain soils of south eastern United States. Soil Sci. Soc. Am. Proc. 10: 381-391. 1945.
16. DANA, E.S. A textbook of mineralogy with an extended treatise on crystallography and physical mineralogy. pp. 1-851. John Wiley and Sons, Inc., New York. 1948.
17. ELLIS, J.H. The soils of Manitoba. Manitoba Economic Survey Board, Winnipeg. 1938.
18. FRY, W.H. Petrographic methods for soil laboratories. U.S.D.A. Tech. Bull. 344. 1933.
19. GOLDTHWAIT, J.W., KRUGER, F.C. Weathered rock in and under drift in New Hampshire. Geol. Soc. Am. Bull. 49: 1183-1198. 1938.
20. GLASSEY, T.W. Notes regarding soils and vegetation of south west Wyoming. Am. Soil Survey Assoc. Bull. 15. 1934.
21. GRIM, R.E. Modern concepts of clay minerals. Ill. State Geol. Survey Report. 80. 1942.
22. HART, R. A detailed study of a region characterized by diverse rocks and partly covered by glacial drift. Jour. Agr. Sci. 19: 90-105. 1929.

23. HART, R. Soils of south eastern Scotland. Jour. Agr. Sci. 19: 801-813. 1929.
24. HASEMAN, J.F., MARSHALL, C.E. The use of heavy minerals in studies of the origin and development of soils. Mo. Agr. Exp. Sta. Res. Bull. 387. 1945.
25. HENDRICH, J., NEWLANDS, G. The value of mineralogical examination in determining soil types with a method of examination and a comparison of certain English and Scottish soils. Jour. Agr. Sci. 13: 1-17. 1923.
26. JACKSON, M.L., WHITTIG, L.D., PENNINGTON, R.P. Segregation procedure for the mineralogical analysis of soils. Soil Sci. Soc. Am. Proc. 14: 77-81.
27. JEFFRIES, C.D. The mineralogical composition of the very fine sands of some Pennsylvania soils. Soil Sci. 43: 357-366. 1937.
28. _____, WHITE, J.W. Mineralogical soil analyses as an aid in soil classification. Soil Sci. Soc. Am. Proc. 4: 364-367. 1939.
29. _____ Some mineralogical characteristics of limestone soils of different localities. Soil Sci. Soc. Am. Proc. 5: 304-308. 1940.
30. _____, YEARICK, L.G. The essential mineral content of the principle soil series of Union County, Pennsylvania. Soil Sci. Soc. Am. Proc. 13: 146-152. 1948.
31. JOEL, A.M. Predominant Saskatchewan soil profiles correlated with soil development factors in Northern latitudes. Proc. First Internatl. Cong. Soil Sci. 4: 200-222. 1927.
32. KELLEY, W.P., DORE, W.H., WOODFORD, A.D., BROWN, S.M. The colloidal constituents of California soils. Soil Sci. 48: 201-255. 1939.
33. _____, PAGE, J.B. The colloidal constituents of American alkali soils. Soil Sci. 51: 101-124. 1941.
34. KILMER, V.J., ALEXANDER, L.T. Methods of making mechanical analyses of soils. Soil Sci. 68: 15-24. 1949.

35. KRUGLER, F.C. A sedimentary and petrographic method of certain glacial drifts of Minnesota. Am. Jour. Sci. 34: 345-363. 1937.
36. LARSON, W.E., ALLAWAY, W.H., RHOADES, H.F. Characteristics of the clay fraction of various horizons of Scott silt loam and Pawnee silt loam. Soil Sci. Soc. Am. Proc. 11: 443-447. 1946.
37. LAURITZEN, C.W., STEWART, A.J., Soil volume changes and accompanying moisture and pore space relationships. Soil Sci. Soc. Am. Proc. 6: 113-116. 1941.
38. _____, Apparent specific volume and shrinkage characteristics of soil materials. Soil Sci. 65: 155-179. 1948.
39. LEAHLY, A. Leaching of mineral matter in some Alberta soils. Sci. Agr. 13: 7-15. 1932.
40. LEAMER, R.W., SHAW, B. A simple apparatus for measuring non capillary porosity on an extensive scale. Jour. Am. Soc. Agron. 33: 1003-1008. 1941.
41. LUTZ, J.F., LEAMER, R.W. Pore size distribution as related to permeability of soils. Soil Sci. Soc. Am. Proc. 4: 28-31. 1939.
42. LYON, L.T., BUCKMAN, H.O. The nature and properties of soils. pp. 1-499. The Macmillan Co. New York. 1943.
43. MARSHALL, C.E., JEFFRIES, C.D. Mineralogical methods in soil research: The correlation of soil types and parent materials with supplementary information on weathering processes. Soil Sci. Soc. Am. Proc. 10: 397-405. 1945.
44. NATELSKI, R., TURK, L.M. Heavy minerals in some podzol soil profiles in Michigan. Soil Sci. 64: 469-487. 1947.
45. MOSS, H.C. The morphology and composition of Saskatchewan podzolic soils. Sci. Agr. 18: 708-718. 1938.
46. NAGELSCHMIDT, G., DESAI, A.D., MUIR, A. The minerals in the clay fractions of a black cotton soil and a red earth from Hyderabad Deccan State India. Jour. Agr. Sci. 30: 639-653. 1940.

47. NELSON, W.R., BAVER, L.D. Movement of water through soils in relation to the nature of the pores. Soil Sci. Soc. Am. Proc. 5: 69-76. 1940.
48. NEWTON, J.D., WARD, A.S., BENTLEY, C.F. Wooded soils and their management. Univ. of Alberta. Bull. 21. 1948.
49. ODYNSKY, W., NEWTON, J.D. Soil survey of the Rycroft and Watino sheets. Univ. of Alberta. Bull. 53. 1950.
50. PEARSON, R.W., ENSMINGER, L.E. Types of clay minerals in Alabama soils. Soil Sci. Soc. Am. Proc. 13: 153-156. 1948.
51. PETERSON, J.B. The effect of montmorillonite and kaolinitic clays on the formation of platy structures. Soil Sci. Soc. Am. Proc. 9: 37-48. 1944.
52. _____ Relation of parent materials and environment to clay minerals in Iowa soils. Soil Sci. 61: 465-475. 1946.
53. RICHARD, J.A., CHANDLER, R.F. Some physical and chemical properties of mature podzol profiles. Soil Sci. Soc. Am. Proc. 8: 379-383. 1943.
54. RICHARDS, L.A. Low vacuum pressure control apparatus. Rev. Sci. Instr. 2: 49-51. 1931.
55. RUSSELL, J.E. Soil conditions and plant growth, pp. 1-635. Longmans, Green and Co. Toronto. 1950.
56. SANDERSON, J.O.G. Criteria for determination of Alberta sandstones. Msc. Thesis, University of Alberta. 1923.
57. SHAW, C.F. A method for determining the volume weight of soils in field condition. Amer. Soc. Agron. 9: 38-42. 1917.
58. SMITH, R.M., BROWNING, D.R., POHLMAN, G.G. Laboratory percolation through undisturbed samples in relation to pore size distribution. Soil Sci. 57: 197-212. 1944.
59. STEELE, J.G., BRADFIELD, R. The significance of size distribution in the clay fraction. Am. Soil Survey Assoc. Bull. 15. 1934.

60. U.S.D.A., U.S.D.A. guide for textural classification. Bureau of Plant Industry, Soil and Agricultural Engineering. Washington. 1948.
61. U.S.D.A., Soil survey manual. Handbook 18. Washington. 1951.
62. WILLIAMS, B.H., BOWSER, L.W. Grey wooded soils in parts of Alberta and Montana. Paper to be presented to Soil Sci. Soc. Am. 1952. (unpublished.)
63. WYATT, F.A., NEWTON, J.D., MATHER, T.H. Soil survey of St. Ann sheet. University of Alberta. Bull. 20. 1930.
64. _____, DOUGHTY, J. The sulfur content of Alberta soils. Sci. Agr. 8: 549-555. 1928.
65. _____, NEWTON, J.D. Alberta soil profiles. First Internatl. Cong. Soil Sci. 4: 358-366. 1927.

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